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THE COOK ISLANDS

Settlement in an Island Group of the South-West Pacific[1]

By W. B. JOHNSTON

THE CULTURAL landscape contains many elements through which to study the profound effects of the impact of Western civilization upon the native peoples of the Pacific islands. Frequently, an analysis of the forms and patterns of settlement is particularly revealing. This is true of the Cook Islands where a century and a half of European contact has resulted not only in a general movement of villages to the coast but has also effected striking changes in the form of the village and in the house type.

The Cook Islands lie near the southern margin of the vast, triangular, island-studded and oceanic area of Polynesia, and are politically and economically an integral part of the Dominion of New Zealand (1)[2] (Fig. 1). The fifteen islands which constitute the 100 square miles of land in this insular tropical "province," are dotted over an ocean surface of 850,000 square miles. The islands are readily divisible into two contrasting physical groups. The seven islands of the Northern Group are all coral atolls or "low" islands; those of the Southern Group are primarily volcanic or "high" islands and include the major units of land area, population and agricultural production (2).

It was during the period of dominant missionary influence from 1830 to 1880 that the major changes in settlement took place (3). Dating from these years are many of the burnt-lime dwellings which, partially in some islands and almost completely in others, have replaced the native type. Moreover, it was at this time that the native villages were attracted to the coast and divorced from their original sites on inland terraces and slopes. The most drastic changes have occurred on the "high" island of Rarotonga which, as the administrative and commercial centre for the whole group, has been the focus of exotic influences. This island supports over one-third of the 15,000 inhabitants of the Cook group on only one-quarter of the total land area.

This paper deals generally with settlement in the Cook Islands as shown by the study of Rarotonga and, with reference to a specific tribal district, analyses the forms and patterns there exhibited. It should be noted that the choice of the island of Rarotonga means the presentation here of what is probably an extreme case. Nevertheless, this procedure is justified since it indicates the fundamental nature of the changes which other islands all too frequently appear to be trying to emulate.

THE GENERAL PATTERN ON RAROTONGA

The Polynesian is a gregarious person and this is reflected in the dominance of the village as the characteristic unit of settlement. Excluding the twin settlement of Avarua-Avatiu, which forms the functional capital of the Cook Islands, there are five villages sited at irregular intervals around the coast (Fig. 2). These are essentially agricultural settlements. To a certain extent they may function as dormitory centres supplying labour to the offices, schools, trading stores, hospital and wharves of Avarua-Avatiu, but on

1. Acknowledgement is gratefully made to numerous officials and departments of the Cook Islands Administration for their willing co-operation.

2. Figures in parentheses in the text refer to the works listed on pp. 10-11.

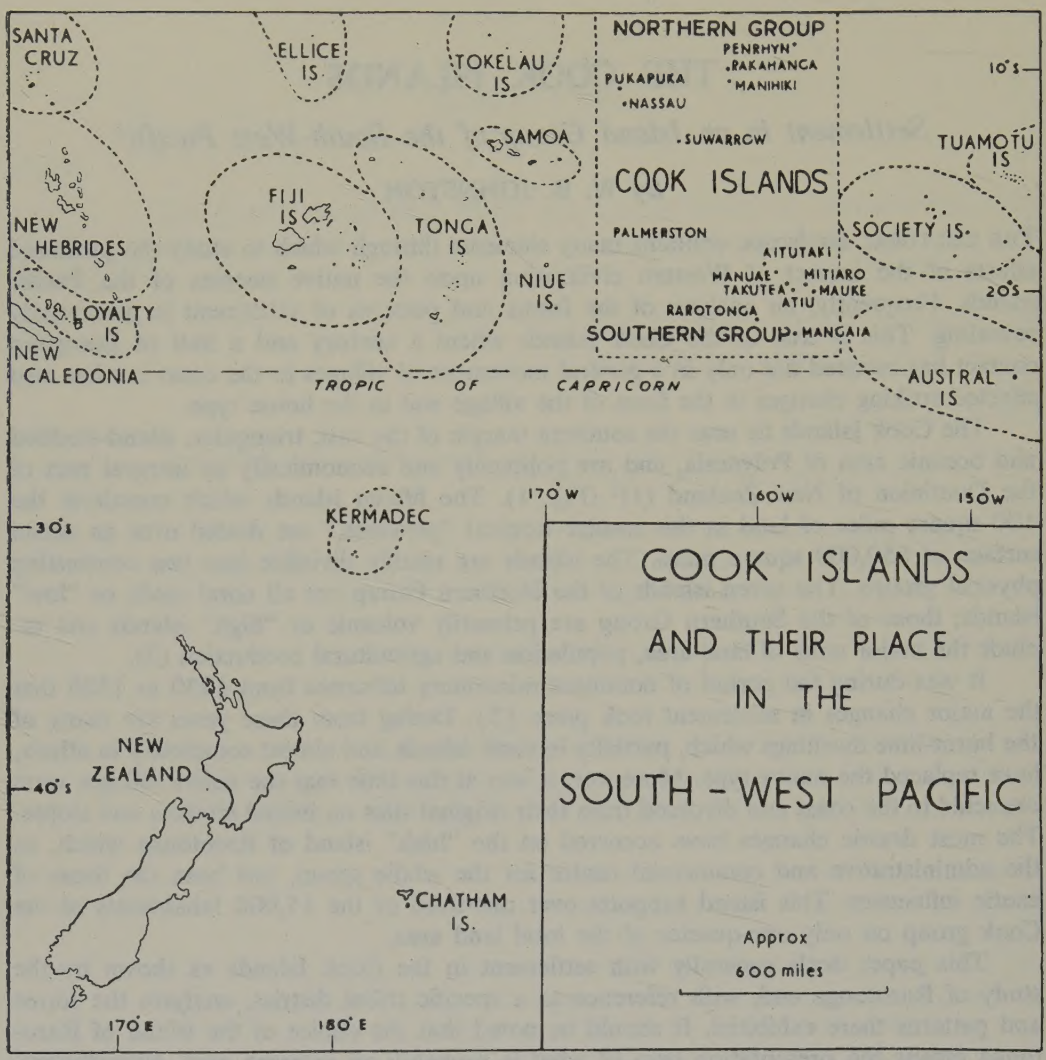

Fig. 1. The fifteen islands of the Cook Group total 100 square miles of land and are spread over 850,000 square miles of ocean.

the whole they maintain close ties with the village lands of which they are still an integral part. That these villages and their lands are mutually interdependent is clearly shown by the concentration of four of the five villages on the eastern coastlands which are at once the largest tracts of lowland and the most productive and intensively utilized.

The twin settlement of Avarua-Avatiu is distinct from any other on Rarotonga or on any other island in the whole group. Here is repeated on a small scale the character of, for example, Suva in the Fiji Islands or Apia in Western Samoa. The sharply differentiated native and European residential sections, the localized settlements of natives from particular islands, the commercial area and the administrative block, the whole oriented towards the wharves and shipping facilities—all these and many other common features are to be recognized. A detailed study of the twin settlement is considered, however, to be beyond the scope of this paper.

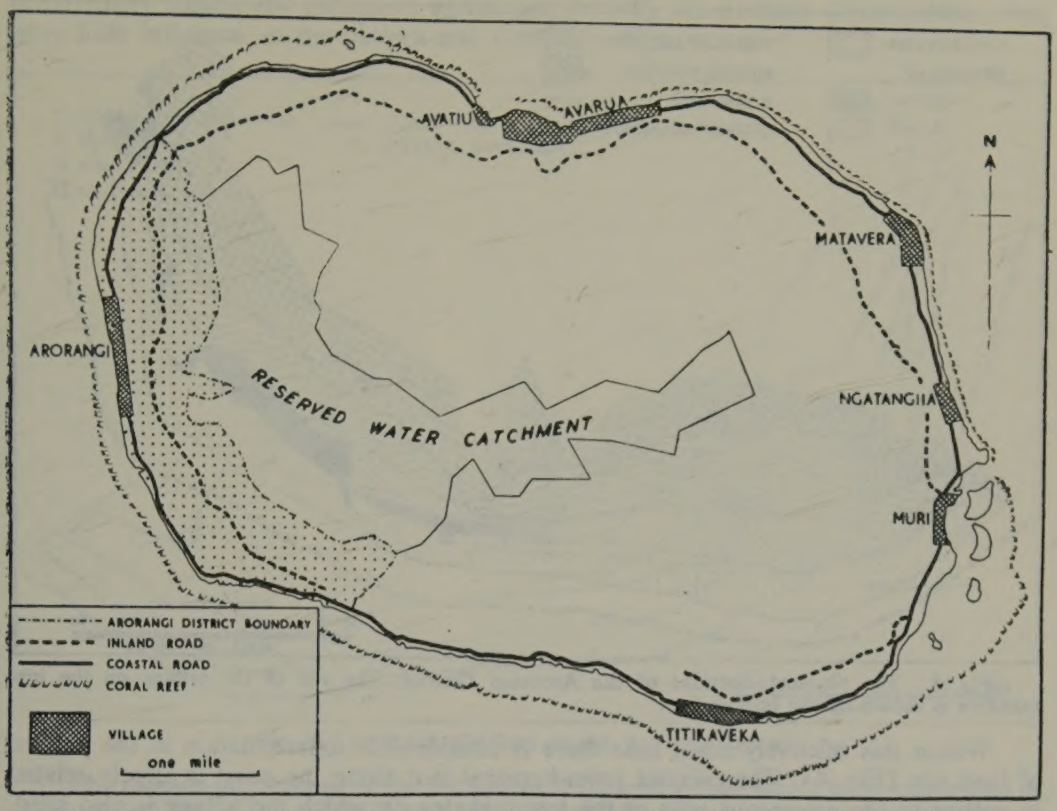

Fig. 2. Rarotonga, with an area of twenty-five square miles, is the second largest island in the Cook Group and economically and administratively is the most important.

The western half of the island contains only one village which is located approximately in the centre of a narrow, semi-circular belt of lowland which gives way abruptly inland to the high, upstanding, razorback ridges which themselves lead up to the jagged crestlines of the main ranges. It is to this area that particular attention is given.

The Arorangi District: Basic Features

The Arorangi District constitutes the western segment of the island and occupies less than one-fifth of the total land area. It has over 1,000 persons, that is, one-fifth of the population of the island of Rarotonga. With a coastline of approximately five miles, the District reaches one mile inland at the deepest point, while the narrowest section is less that half a mile (Fig. 2). The narrow depth of the District appears at first sight to be unusual, since it is very common for tribal lands to reach from the sea inland to meet at the centre of an island. In the case of Rarotonga, a large proportion of the rugged interior is now reserved as a water catchment. However, the area does still range from fringing coral reef into the volcanic mountainous interior, and thus includes within its present boundaries a part of all the major physical units into which the island is conventionally divided (4): coral reef and shallow lagoon, low makatea or raised coral strand, depression, terraces and fans, and volcanic mountainous interior (Fig. 3).

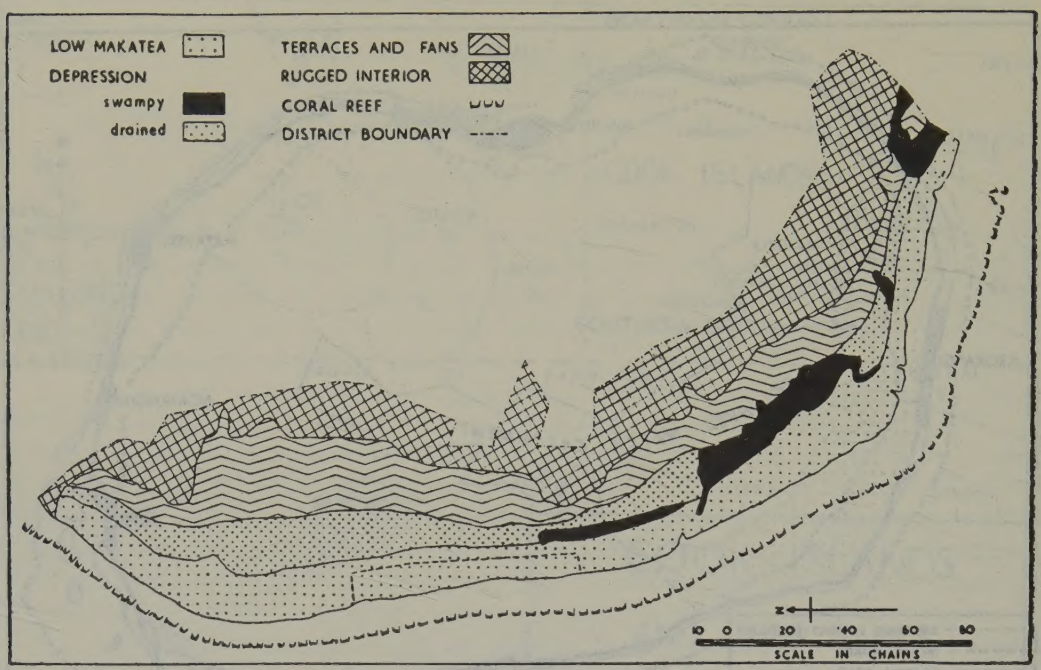

Fig. 3. The physical divisions of the Arorangi District. The site of the village on the low makatea is shown by the broken line.

Within this relatively small area there is considerable differentiation in the pattern of land use (Fig. 4). The coconut palm-kumara[1] belt along the coast is clearly related in outline to the calcareous soils of the low makatea on which the village is also sited. Within this belt many acres have reverted to secondary forest and scrub. Inland lies the taro swamp, a narrow, low-lying, discontinuous zone of irrigated land occupied by plots of taro *(Colocasia esculenta)* which are interspersed within the now-dominant spread of hibiscus and guava. The third region forms the most productive area and includes the fertile soils of the depression, where well drained, and of the terraces and fans. Oranges and tomatoes are the major commercial crops but various subsistence crops also find a favourable environment. Here is found, *par excellence,* the variety of crops from area to area, from season to season, and from year to year, which is the most impressive and distinctive feature of land use. The unused or non-agricultural land, under secondary forest and scrub, is closely associated with the steep slopes, narrow valleys and radiating ridges of the rugged interior.

Therefore the agricultural land approximates to the physical divisions of terraces and fans, depression and low makatea. It is peripheral, narrow and low-lying. It provides the site for the whole of the settlement and the route for all roads and important tracks. The road, which forms the main highway, hugs the coast; an historic track—*ara metua*—marks roughly the inner limit of the depression and formerly linked the pre-missionary villages which were sited on higher ground, inland of the unhealthy swamp and coast and adjacent to the major crop-lands.

Most of the land is owned by the natives who utilize it within the two typical systems of native-commercial and native-subsistence agriculture. European-owned land

1. Sweet potato.

is extremely limited and plantation agriculture virtually non-existent. Consequently, they have little influence on the pattern and form of settlement.

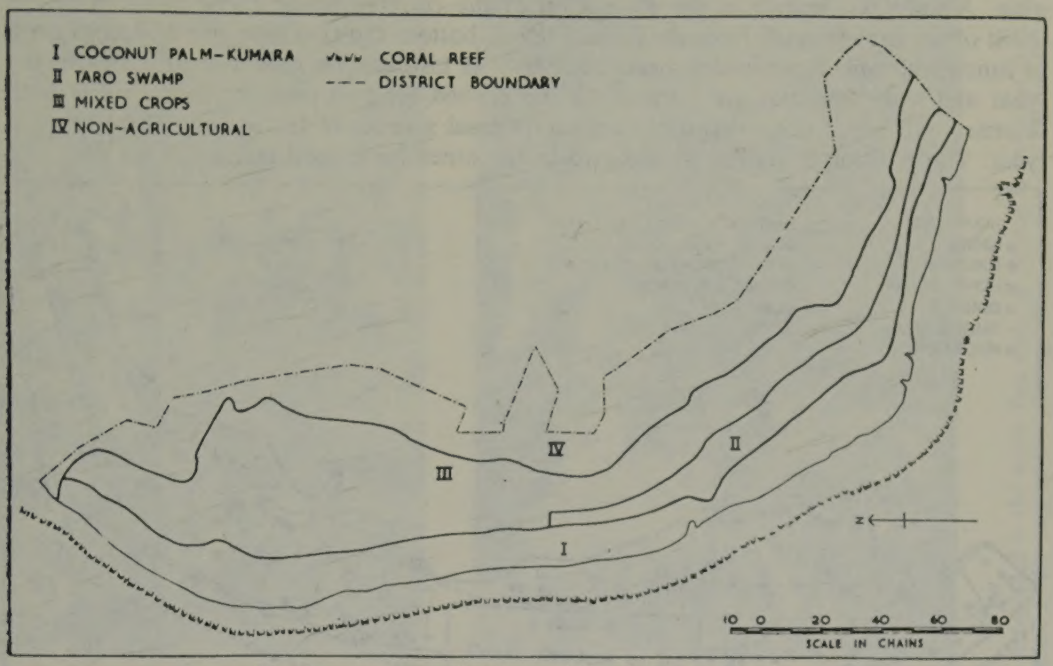

Fig. 4. Land-use divisions of the Arorangi District.

The outstanding feature of the settlement is the one village which is an expression of the traditional communal organization of native life (Plate I, top left). A second important element is the frequency of houses of European type which represent well over one-third of the dwellings in the Arorangi District. Equally characteristic is the relatively sparse settlement within the main agricultural areas, and the marked concentration along the coastal road. Of all these features, only the village unit (but neither its present site nor form) is typical of pre-missionary days. All the others reflect the impact, direct or indirect, of Western influences.

House Types and their Distribution

An analysis of house types in the Arorangi District provides interesting results. The dwellings have been classified into one of three types and their distribution mapped (Fig. 5).

The native type of house consists of a stout framework of breadfruit and coconut trunks (Plate I, bottom left). Where available other material may be used, for instance, *tamanu (Calophyllum inophyllum)* although with the depletion of the timber reserves it is now a scarce resource. The walls are built of vertical slats of hibiscus, a plant which grows wild over most of the island and therefore furnishes an almost unlimited supply (Plate II, top left and right). The roofing material is *kikau,* the leaf of the coconut palm. Before plaiting, the leaf is usually soaked in sea water to rid it of beetles and, thus, to prolong the life of the thatch. The native house or *hare* is built on the levelled surface of the ground. The floor is covered with coral gravel while lumps of coral and basalt mark out the pathways and border the rectangular *paepae* in front of the *hare* (5). Not all

these traditional features necessarily find expression in every native type of house or even in the majority of them. In essence, however, they conform to the general description. A universal feature is the separation of the cooking house *(hare umu),* which is built of similar material, from the *hare* (Plate I, bottom right). These two buildings form a functional unit. Storehouses are unnecessary as taro can be grown at all times of the year and some varieties are "stored" in the ground for two years or more, while both kumara and breadfruit—two other important local sources of food—have three crops a year. The position is similar with regard to the other basic food crops.

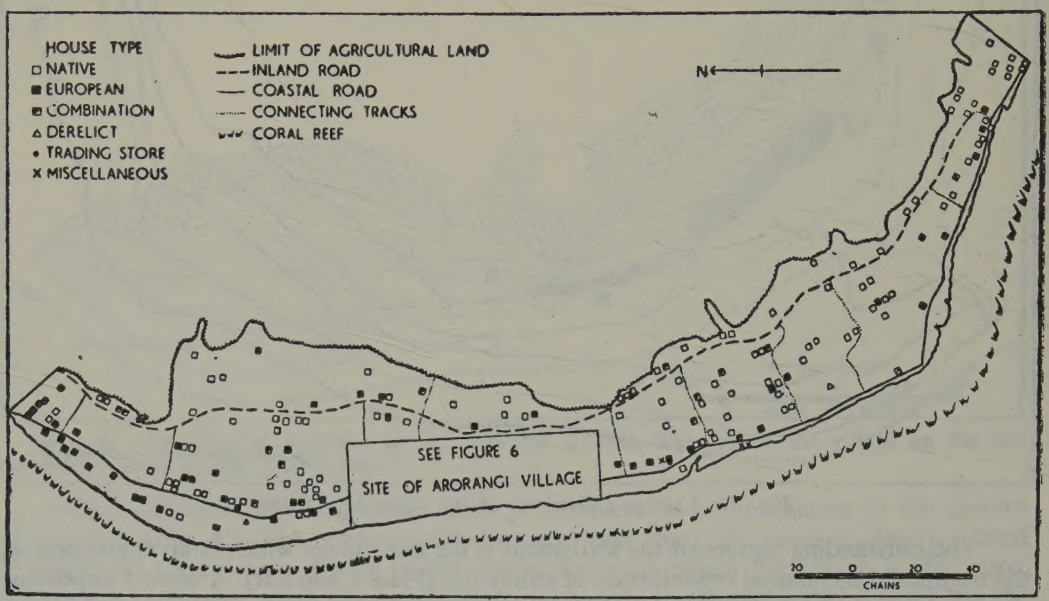

Fig. 5. Dispersed settlement in the Arorangi District.

The native type of house is widely distributed throughout the District (Fig. 5). It is not, however, typical of the village where only one-eighth of the dwellings are of this type (Fig. 6). Beyond the limits of the village the *hare* is the characteristic dwelling and constitutes two-thirds of the houses. Approximately one-half of the rural *hare* are located in the neighbourhood or inland of the *ara metua.* The remainder are dispersed throughout the agricultural area: none are actually located within the taro swamp although they are to be found on its margins. Moreover, it should be noted that not all of the native type of houses shown on Figure 5 are used as permanent dwellings. Although the bulk of them are so used, some are occupied only for a few days at a time, while the family are at work on their land.

The European type of house is an adaptation of European styles to local materials and requirements (Plate II, bottom left and right). The walls are built of burnt-lime which comes from the burning of coral for two or three days on a smouldering pile of green timber that is stacked in a square pit dug in the sandy makatea (Plate I, top right). The material for the roof is, almost universally, corrugated iron sheets. Frequently, the foundations are raised above the general level of the ground by a base of stones or coral. This is not a native custom and neither does a higher foundation indicate a more important occupier as is the case of the *fale* of Western Samoa. In the Cook Islands it is yet another result of Western influence. In numerous instances this house type has no ceiling and frequently only one room, while the majority of houses have wooden floors.

Top left: Communal work on a village building in Arorangi. Burnt-lime is being used in the walls. *Top right:* A pit dug in the coral sand of the makatea in preparation for the burning of the coral lumps which are stacked at the edge of the clearing. Green timber will eventually be laid in the pit, set alight, and the coral piled on top. *Bottom left: Hare* or native-type houses at various stages of construction. Plaited coconut leaves form the roof, slats of hibiscus the walls, while both coconut and breadfruit timber is used in the framework. *Bottom right: Hare umu*, or native type of kitchen serving the *hare*, which is visible in the right background.

PLATE II

Top left: A trio of *hare* along the historic track which runs immediately in front of them. The straggling group of scraggy banana plants and the camouflaged aspect of the houses are typical features of the older sites. *Top right:* This group of coastal *hare*, beneath coconut palms and pawpaw trees on the low makatea, shows their more open setting. *Bottom left:* European-type houses in the village of Arorangi. The raised foundation, corrugated iron roof, burnt-lime and timbered walls are typical features. *Bottom right:* The appearance of the backyards of European-type houses in the village.

Fig. 6. The morphology of the Arorangi village.

The European type of house is the distinctive unit of the village, comprising as it does two-thirds of the dwellings (Fig. 6). Nearly all of the remainder of this type are located near the coastal road (Fig. 5). Although occupied primarily by natives, a few of those concentrated near the northern margin of the District are occupied by Europeans who are employed by the Administration in Avarua. With minor exceptions there is a notable absence of houses of the European type along the historic inland track.

This type of house, which dates from the early missionary period of the first half of the nineteenth century, was introduced for the use of missionaries while similar materials were used in the construction of numerous churches. With the increasing influence and prestige of the Europeans, it became a mark of social advancement for the native to build in the same style and with similar materials of burnt-lime and corrugated iron. The houses are a legacy of a more prosperous era. Maintenance has long been neglected and they are now in a dilapidated condition. It is noteworthy, however, that in the adoption of the European type the native has retained the commendable practice of constructing kitchens as separate buildings away from the house proper. This is acknowledged as a valuable feature in tropical climates.

Innumerable combinations of the two basic types exist. The common combination consists of a *kikau* roof with walls of flattened kerosene tins, petrol drums, or wooden box-ends. The standard of many deteriorates rapidly to that of mere hovels. Compared with the native and European types they are few in number, but over one third are located in the village and there they outnumber the native type of house.

The Village of Arorangi

The village has always been characteristic of Polynesian society. In many ways, particularly in site and form, the villages in the Cook Islands have changed with the impact of Western civilization. On Rarotonga, remnants of possible sites of pre-missionary villages exist where the volcanic soil on higher ground, inland of the depression,

is studded with lumps of coral or stained with coral sand that once may have covered the floors of houses and bordered the pathways leading to them.

The missionaries, in building their churches on the coast, added a powerful impetus to the new influences that were in other ways unsettling the traditional village life and communal organization of the natives. The outcome was the wholesale movement of natives to coastal villages which grew up around the churches. This movement was repeated in the outer islands with the exception of Atiu, where the five settlements cluster together on the interior plateau. In all cases, however, the church replaced the *marae*—in some ways the equivalent of the English village green but of even wider significance—as the material expression of village unity. Further, as already seen, the type of house changed. To-day the healthy, well-ventilated, rectangular *hare* is no longer typical of the village. In its place rise the obvious, white, burnt-lime walls and rusty, corrugated-iron roofs which most decidedly do not mellow with time to merge into the surrounding countryside as do the indigenous constructions. (Compare Plate II, top left and right with Plate II, bottom left and right).

The Arorangi village exhibits these contemporary features. In other ways as well it is representative of settlement in the Cook Islands. The village consists of a string of buildings along the coastal road which passes through the length of the village to form the main line of circulation (Fig. 6). The location of the three churches, one near the middle with one towards each end, emphasizes the ribbon form. The church fulfils a social as well as a religious function: it is to a degree the modern social force binding together the members of the village and District who no longer find in their tribal chiefs the leadership and power which was formerly so effective.

The villagers prefer to buy most of their goods from the island's main shopping centre of Avarua, some five miles distant round the northern coast. The local trading stores, five in number, occupy either a converted part of a European type of house or a lean-to. They are small in size and cater for the popular demand, primarily tinned meats and fish, biscuits, candles, kerosene and similar commodities. Some are owned by members of the village community while others are branches of large trading stores whose local headquarters are in Avarua. The existence of five in the village and the thriving trade that they do is not really an indication of financial prosperity but rather a measure of the dependence of the native population upon store goods, a dependence which takes them out of the category of semi-luxuries into that of basic necessities.

In addition to the trading stores there is one small bakery in the village and a larger one to the south. They supply local needs as well as meeting in part the demand from Avarua-Avatiu. Wood for fuel is cut and collected in the vicinity of the bakeries from the stands of secondary forest and scrub that occupy a significant proportion of the area of the coastal makatea. The bakeries are family industries and, therefore, are of no significance as employers of labour. Other industries include a small copra kiln utilizing the husks of the coconuts for fuel. An important building for wage-earners and cultivators alike is the fruit-packing shed. To this large establishment for inspection, grading, packing, counting, and for gassing when necessary, comes all the fruit grown in the District for export. Here is provided an important source of employment, especially for women and girls, during the harvest season when it becomes the focus of activity in the District.

The school provides elementary primary education for the children of the District and is one of the four Government schools on the island. It has the second largest roll, totalling over 300 pupils. One aspect of the recreational side of village life, and an

indication of New Zealand influence, is represented by the rugby football field which has been laid out on a portion of the depression behind the village (Fig. 6).

In the Arorangi village are represented all the house types found in the District (Fig. 6). The dominance of the European type is indisputable. Of the ninety-two houses, sixty-six, or more than two thirds, are in this category. The next most common, totalling fourteen, is the combination type, while only twelve are built in the native style.

Overcrowding of each dwelling is evident but it cannot be considered an important problem in comparison with the situation in Western Samoa or even amongst the Maori population of New Zealand. The section upon which the house stands is tiny but despite the small area it is all too often in a neglected state with few flowers, many weeds and long grass in front, and a backyard littered with old tins and other oddments. This has importance since the vector of filariasis on Rarotonga, *Aedes pseudoscutellaris*, breeds in temporary accumulations of water in small containers such as coconut shells, bottles and tins. The position was drastic before the inauguration of a regular rubbish collection in 1946. Since then there has been striking evidence of the efficiency of the anti-mosquito routine.

The houses are supplied with water piped from the reservoirs of the inland catchment area. Inhabitants of houses beyond the village and away from the coastal road have to carry water from the piped supply or depend on shallow wells, all of which are of poor construction and exposed to the risk of dangerous pollution. A peculiar feature is the siting of ablutions in the front of the section close to the road. The water is led, via bamboo pipes, from the piped supply to the washing place which is partially sheltered from observation from the road by a low frame of coconut matting or sheets of corrugated iron.

A final element in the morphology of the village is the derelict building. There are seven of them in the village with more in the rural areas (Figs. 5 and 6). They are the remains of houses of European type that have been partially destroyed by the high winds or storm waves associated with the periodic visits of hurricanes. The weedy section and gaunt vine-covered walls of burnt-lime, open to the sky, add yet another touch of neglect.

Viewed from the sea or from the air, the village is lost in a wealth of vegetation. During the greater part of the year there is little to distinguish the village site from the rest of the vegetation-covered makatea. But for a couple of months of summer, at the end of the year, the location is brilliantly indicated by a long gash of bright red amidst the varied tints of green. For this is the season of the glorious flamboyants which add a vivid splash of new colour to the green of the vegetation, the white of the lime walls and coral beach, the brown of the rusty roofs and the grey of the road. The untidy surroundings and neglected buildings of the village are sadly out of character with the beautiful setting. A comparison with villages of other island groups of Polynesia, and even with the same villages twenty years ago, shows that those of Rarotonga bear little resemblance to the traditional Polynesian village.

The Current Problem

The native appears to have lost pride in his village. Unkempt sections, overgrown gardens, absence of flowers, scattered refuse—these and other observable features indicate a lack of interest. It is emphasized by the toleration of hovels; for example, many houses of the combination type are in this state. Even in the rural areas this is apparent. In the case of the *hare* a supplementary feature has added to the problem.

The *hare*, now roofed with *kikau* on Rarotonga, formerly bore a lasting thatch of pandanus leaves as do those of many of the other islands today. In Rarotonga the extinction of the valuable pandanus in the 'twenties of the present century, was brought about by the introduction of a mealy bug disease. This has forced on the native the use of *kikau* thatch which suffers from the major disadvantage of a very short life. It lasts barely two years while pandanus has a useful life four or five times as long.

The use of coconut leaves for roofing necessitates continual attention if it is to remain rainproof. Further, it has meant the complete replacement of the roof at least every two years. Here indeed is an important consideration since the supply of leaves must come from the available coconut palms. These are already limited in number and the large and continual demand placed upon them for this and many other purposes has resulted in excessive defoliation to the detriment of the nut harvest and, eventually, to the condition of the palm itself.

Neglect and lack of care is readily apparent in the use of the land. The native is omitting to grow many of the staple subsistence crops. Taro plots now occupy only a limited area and even these small remnants are often weed-infested. Most drastic of all is the lack of coconut replanting. The unhappy position in which the Cook Islanders find themselves has been frequently expressed and is variously described as frustration, passivity or negatism (6).

A recent survey provides some interesting figures for the Arorangi village (7). The survey covered sixty-three families and the general conclusion was that poverty was evident in most of them. Of the adults in the group, fifty were entirely dependent on products from their cultivations, thirty-one supplemented the supply from their land by working regularly for wages, while twenty-one, or one third of those surveyed, were entirely dependent on wages. An unduly large proportion of these low incomes was spent on imported foodstuffs. It appears that even families with relatively large areas of citrus trees and tomatoes, the two principal export crops, find their economic status difficult because of irregular shipping facilities and the absence of cool storage for fruit maturing between shipments. The report concludes the section by quoting a recent observer. "The native Rarotongan is losing his pride in his race, in his native household arts and traditional recipes for native foodstuffs . . . He lacks the traditional native authority for the proper growing and conservation of his natural food crops . . ."

Clearly, this emphasizes that the problems of settlement, presented here through a study of the present character of village and rural house, form but one facet of a much wider and more fundamental problem. The traditional Polynesian village is a fine expression of a proud and sturdy people: the modern counterpart, on Rarotonga in particular, and to a less extent in the other islands of the Cook group, is thus all the more disappointing.

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BIOGEOGRAPHICAL ASPECTS OF SETTLEMENT IN MALAYA

By B. W. HODDER

ONE OF THE consequences of the extension of settlement in Malaya has been an increased awareness of the biogeographical problems involved. Of these probably the most important is disease. As many writers have concluded, health is the main problem in the settlement and development of tropical countries.[1] But other problems, too—such as those relating to drinking water, soil erosion, and physiological reactions to climate—may be critical in the success or failure of man's colonization of the equatorial regions.

MALARIA

Malaria has been a formidable obstacle to the work of planters and other settlers in Malaya and helps to explain why large tracts of land remain undeveloped. The disease was for long a problem in the coastal Straits Settlements—in Penang, for instance, one third of all deaths were attributed to malaria in 1829[2]—but it only became prevalent throughout the peninsula during the last quarter of the nineteenth century and the beginning of the twentieth, when great strides were made in the opening up of the country to tin and rubber. Singapore was inevitably affected, for it was the gateway through which infected subjects passed into Malaya from some of the most malarious countries of the world.[3] In the expanding rubber plantations of the interior the problem became acute. Urban centres, too, were affected; within two months of being opened in 1901, Port Swettenham was closed because of malaria.[4]

As late as 1938 malaria accounted for 30·6 per cent of deaths from all causes in the Federated Malay States, but in Malaya as a whole today malaria has lost its menace as the chief killing disease.[5] It has been reduced by area-control measures, increased immunity and personal prophylaxis to an endemic burden of sickness.[6]

It is easy in Malaya to find a correlation between the distribution of malaria and the distribution of population. Well established, densely populated padi areas on the flat coastal plains, as in Kedah, Province Wellesley and Kelantan, urbanized areas like Singapore, and the western interior foothill belt of rubber and tin-mining settlements are relatively free from malaria. In Trengganu, "the coast line, where the bulk of the population is located, is comparatively free [from malaria]; inland from the coast the incidence rises rapidly."[7] The worst malaria occurs in isolated valleys flanked by steep, jungle-clad slopes, in which the populations are more often numbered in hundreds than in thousands (Fig. 1).[8] But these remarks do not establish a simple casual relation: it is not true that the pattern of population distribution in Malaya is determined by the distribution of malaria. The absence of malaria in populated areas is often the effect rather than the

1. See, for instance, P. Gourou, *Les Pays Tropicaux* (Paris, 1948), p. 14.
2. A. A. Sandosham, *Malaria in Malai* (Singapore, 1945), p. 4.
3. Ibid.
4. M. Watson, *The Prevention of Malaria in the Federated Malay States* (Liverpool, 1911), p. 27.
5. By 1949 only 4·5 per cent of deaths in the Federation of Malaya were attributed to malaria.
6. In most malarious areas the sickness rate is far higher among children than among adults, and "the signs of oft-repeated malaria . . . have their own story to tell of the hazards of the slow immunising process whereby adults gain their immunity." See *Federation of Malaya: Report of the Medical Department for the year 1949* (Kuala Lumpur, 1950), p. 41.
7. *State of Trengganu Annual Report for the Year 1949* (Alor Star, 1950), p. 25.
8. *Report No. 19 of the Institute of Medical Research* (Kuala Lumpur, 1951), p. 11.

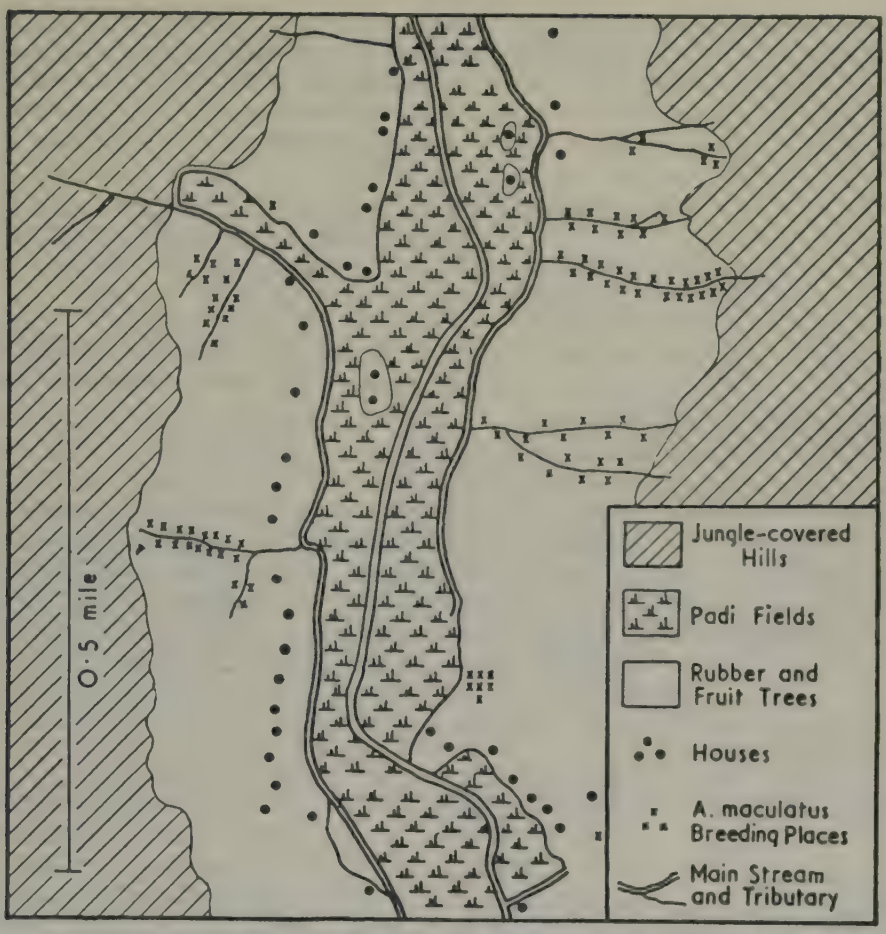


Fig. 1. Part of the Inas Valley, showing the distribution of houses in relation to padi-fields and the breeding places of *Anopheles maculatus* (Based on Fig. IV of *Report No.* 19 *of the Institute of Medical Research,* Kuala Lumpur, 1951).

cause of settlement; anti-malaria measures are best developed in the most populous districts.

A further complication is introduced by the varying environmental preferences of individual species of malaria vectors. Thus the mosquito vector of malaria is *Anopheles maculatus* in the hilly areas of central and South Kedah and *Anopheles barbirostris* in the flat coastal plains of North Kedah.[1] The environmental preferences of the main vectors in Malaya may be summarized as follows:—

Hilly Areas	*A. maculatus*	This, the most dangerous vector in Malaya, has been called "the scourge of the rubber estates." It is absent from the flat coastal plains and favours hilly, particularly granitic, areas. It is peculiarly a seepage breeder and demands *clear, sunlit conditions.*

1. Tunku Ismail bin Tunku Yahya. *State of Kedah Annual Report for the year 1951* (Alor Star, 1950), p. 30.

Lowland Coastal Areas	*A. umbrosus* and *A. letifer*	These mosquitoes favour peaty, acid water along the coastal plain. *A. umbrosus* is characteristic of the jungle, preferring deep shade. *A. letifer,* however, prefers more light, and is typically found in jungle that is being cleared.
	A. barbirostris	This is similarly a coastal species, but is particularly characteristic of the landward edge of the brackish-water zone.
	A. sundaicus	This species prefers still, sunlit, brackish water.
	A. baezai	This is similar to the above except that it prefers some shade over the brackish water.

High temperature and high rainfall—conditions essential for the breeding of malaria vectors—are found throughout Malaya. Attempts have been made to fit annual rainfall curves to those of the incidence of malaria vectors or to the actual incidence of the disease itself in Malaya. So far little success has been obtained in this direction, though rainfall undoubtedly does influence malaria by affecting the height of the water-table. More success in establishing climatic correlations has attended attempts to relate malaria incidence and wet-bulb temperatures in Malaya (Fig. 2). Research in this direction is, however, handicapped while climatic data are used from widely-spaced stations. The natural physical conditions immediately surrounding the insect and influencing its elective movements—such as illumination, humidity, temperature and air movements—differ from regional averages. The micro-climate has more epidemiological significance than the regional climate.

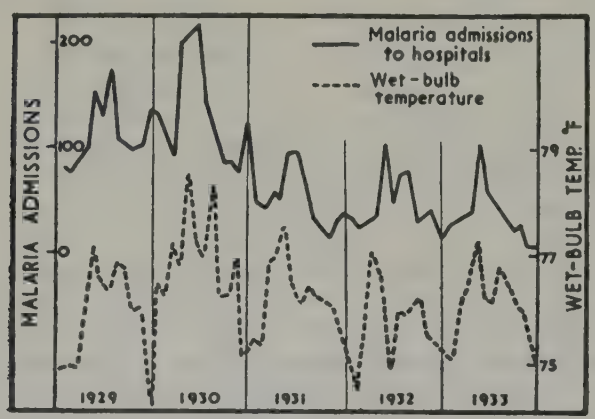


Fig. 2. Correlation of malaria incidence and wet-bulb temperatures in the Tampin district. Based on data given by T. Wilson, "Meteorological Factors as Affecting the Incidence of Malaria", *The Malayan Medical Journal,* vol. 10, no. 2 (Singapore, 1935), pp. 39–48.

The most important vector in Malaya being *A. maculatus*, one of the greatest difficulties in the settlement of the country has been that the insect finds the optimum breeding conditions in cleared jungle in hilly areas. In some countries, for instance Sarawak, clearing of the jungle is the most effective initial step in malaria control: in Malaya clearing of the jungle in the foothills has often increased the danger of malaria. Yet it is exactly in these foothills that most settlement has taken place during the last one hundred years.

Man may unwittingly encourage malaria in three other ways: first, by disturbing the soil. In Singapore, for instance, it is still feared that the rapid, mechanized disturbance of the soil on building sites will precipitate outbreaks of malaria on the island unless the strictest care is taken over malaria control measures.[1] Second, interference with natural

1. See, for instance, W. L. Blythe, *Colony of Singapore Annual Report, 1952* (Singapore, 1953), p. 144.

drainage carries the danger of malaria. Around the coastal areas the mangrove forest, like the rain-forest jungle, has very little malaria; but interference with the free flow of tidal water, such as is entailed by agricultural work in the coastal belt, is one of the commonest causes of outbreaks. When the mangrove is felled and the daily flushing action of the tide is obstructed, *A. sundaicus* and *A. baezai* make their appearance in stagnant pools of brackish water. In felling jungle in the interior, moreover, tree trunks are commonly allowed to fall across ravines and streams, a practice which interferes with the natural drainage of the land, raising the water-table and producing stagnant conditions suitable for the breeding of *A. letifer*.[1] In Singapore, again, malaria outbreaks have been traced to mosquitoes breeding in a river basin where fish ponds have been constructed. The ponds themselves do not breed mosquitoes while in full cultivation,[2] but they have interfered with the natural drainage of the area. The siting of such ponds, therefore, must be done with care. Many engineering projects, too, such as road building and railway construction have left a legacy of malaria by obstructing natural drainage. Third, artificial means of transport and human migrations may cause the dispersal of malaria over wider areas than would normally be affected.

In carrying out anti-malarial measures in rural Malaya, one difficulty is the dispersion of rural settlements. Anti-larval measures, so generally successful in Malaya when used to protect the concentrated populations in towns, villages and estates, are prohibitively expensive in rural areas with a scattered population.[3] Dispersion of dwellings also makes the capture of *Anopheles* difficult, because there is then no focal point in settlements towards which they are attracted. A further complication is that since the various species of vectors have different environmental requirements, malarial control measures must necessarily differ from place to place. Thus, the key to malaria control in an area is knowing the vector species and its breeding habits. "The problem is first, last and always, a local one, success depending upon knowledge of the habits of the particular species of Anopheles concerned and the local peculiarities of topography, population and climate."[4]

Other Diseases

The growth of **scrub typhus** in Malaya, like the growth of some kinds of malaria, has resulted chiefly from cutting down the jungle and so producing a new set of ecological conditions. Scrub typhus vectors, like the chief malaria vectors in Malaya, are uncommon in the virgin jungle. With the increase of waste land and clearings, however, the scrub typhus mite and its chief hosts have increased. "There is evidence that the disease may become more widespread until almost every patch of waste land is suspect."[5]

The areas of proved endemicity of **filariasis**—a worm infection—are the lower courses of the main rivers and along the coastal zone from the Sungei Merbok in Kedah to just north of Butterworth in Province Wellesley. The chief filariasis vectors in Malaya are culicine mosquitoes of the genus *Mansonia*—especially *indiana, uniformis* and *longipalpis*. As in malaria, the vectors vary in their distribution with the physical habitat. Along the coastal plains, in Perak, Province Wellesley and Kedah in particular, the

1. Sandosham, op. cit., p. 119.
2. W. Birtwistle, "Rearing of Carp in Ponds." *The Malayan Agricultural Journal*, Vol. 19 (Kuala Lumpur, 1931), p. 382.
3. *Report No. 19 of the Institute of Medical Research* (Kuala Lumpur, 1951), p. 10.
4. *Report No. 25 of the Institute of Medical Research* (Kuala Lumpur, 1951), p. 173. Control measures based upon such knowledge are known as species sanitation. There is clearly nothing simple about the relation between disease and environmental factors, both physical and cultural. "Such environmental factors are topography, temperature, amount and seasonal distribution of rainfall, fauna, flora, house-types, cultivation practices of the farmers, sanitary habits, location of settlements, and such activities as raising livestock." K. J. Pelzer, "Geography and the Tropics," Chapter 14 of *Geography in the Twentieth Century*, edited by G. Taylor (London, 1953), p. 335.
5. *Federation of Malaya. Annual Report of the Institute for Medical Research for the year 1949* (Kuala Lumpur, 1950), p. 3.

vectors appear to be chiefly *Mansonia indiana* and *Mansonia uniformis* breeding in small patches of open swamp. Many different plants harbour the larvae of these two mosquitoes, but the water hyacinth (*Eichornia crassipes*), certain swamp grasses and water lettuce seem to be among the more important; all have roots hanging free in water. Control of filariasis along these coastal plains, then, involves the destruction of the water hyacinth and of patches of open swamp. In contrast to this, along the lower reaches of the main rivers, notably the Perak, Pahang and Bernam, *Mansonia longipalpis* is the principal vector of filariasis. Settlement is restricted to lêvées along the river banks and is backed by extensive fresh-water jungle-swamp, where the *Mansonia longipalpis* breeds. Control here includes felling the jungle and draining the land.

Yellow fever is carefully guarded against in Malaya as air transport becomes swifter and more frequent, for the peninsula lies between countries highly infected with this disease. There is a steady stream of people through Singapore, the main dispersal centre for the immigrant population of Malaya; Indians in particular come from areas of endemic yellow fever and **cholera**. The latter disease is more common than yellow fever in Malaya, for it may also be spread from countries immediately to the north: an outbreak of cholera in north Malaya in 1946 was traced to Siam.

Tuberculosis accounts for more deaths than any other single disease in Malaya today. Public concern has shifted from a mainly rural disease—malaria—to a peculiarly social disease, associated in its incidence with overcrowding. The tuberculosis rate is especially high in areas of shop-houses—the most common urban dwellings in Malaya, over 50 per cent of the urban population in the Federation living in them.[1] Rooms are frequently divided into one-family cubicles, leading to very high floor-space densities and producing units of accommodation in which there is often no direct access to light or fresh air. According to Morland, "the shop-house must be looked on as the most potent single factor in the production of the high rate of tuberculosis prevalent in Malaya."[2]

Nuisance Mosquitoes

Most mosquitoes in Malaya are not disease vectors: for instance, of the thirty-six species of *Anopheles* recorded in Malaya, only six are significant carriers of the malaria parasite. Nevertheless, most mosquitoes bite man, who, apart from using protective measures such as the mosquito-net, frequently sites his dwelling where mosquitoes are least numerous. In doing so, he considers two factors: first the distance from natural breeding grounds (the length of flight from breeding place to source of blood-meal has been placed in Malaya at a maximum of half a mile for most practical purposes), and second, exposure to local breezes. Yet unfortunately the most common domestic mosquito in Malaya, *Culex fatigans,* prefers to breed not in natural swamps but in water contaminated with organic matter, that is, in collections of foul water from house drains, pools near dwellings and outflows from septic tanks. Other culicine mosquitoes breed in old tins or refuse thrown under and around houses. Human settlement, then, may attract and encourage nuisance mosquitoes. They may also result from the use of prawn-dust fertilizer by Chinese market-gardeners; in urban areas the erection of residential property in districts largely occupied by vegetable gardens gives rise to a clash of interests between householders and gardeners, which has no easy solution.[3]

1. T. A. L. Concannon, "Town Planning in Malaya", *Journal of the Technical Association of Malaya,* Vol. 4, No. 1 (Singapore, 1953), p. 9.
2. A. Morland, "Report of Dr. A. Morland on Tuberculosis in Malaya", *The Medical Journal of Malaya,* Vol. 4, No. 4 (Singapore, 1950), p. 274.
3. *Colony of Singapore, Report of the Medical Department for the year 1949* (Singapore, 1950), p. 44.

Potable Water and Sanitation

It is paradoxical that drinking water should often be scarce in this equatorial environment where rainfall is heavy and continual and where humidity is high. Yet the word *kubang* (water-hole) occurs frequently in Malayan place-names, and in 1940 it was estimated that only 35 per cent of the people of the Malay States were supplied with unpolluted drinking water.[1] The high incidence of enteric fever points to the same conclusion.

Three main reasons may be advanced for the deficiency of potable water in Malaya: first, wells are usually filled by run-off water so that little natural purification by percolation occurs; the location of wells in relation to houses and lavatories is, therefore, of vital importance to health. Only in a few places—for instance, along the east coast, where marine sands reproduce their usual ground-water features—are percolation wells found. Second, the high water-table encourages acidic conditions, and, third, makes it difficult to get rid of night soil and other refuse without polluting well water.

It may be that the common linear pattern of Malay houses along a river, stream or drain is to some extent an adaptation, albeit unconscious, to the environment in that it reduces the ill effects on health of poor sanitary conditions. The river, nearby swamp or jungle, or even shallow pits dug in the compound are made to serve in most cases. Nucleation, rapidly and artificially induced, as in recent resettlement schemes,[2] certainly makes possible the better provision of sanitation and other services, but renders their absence all the more dangerous.

Soil Erosion and Settlement

Malayan rivers, especially those flowing westwards, carry a great amount of silt. There is heavy and continuous erosion up-stream in spite of the thick cover of rainforest, and man has often accelerated the process by mining and agriculture, both of which involve initial deforestation and the consequent exposure of the soil to agents of erosion.[3] In mining areas difficulties are created by the waste discharged into nearby streams.

Some striking effects of erosion and silting on human settlements have been noted in Malaya. Kuala Kubu, for instance, was buried by silt and the settlement abandoned. It lies at the debouchment of the Selangor River from the hills, and the streets of the town were for long protected by a bund. The sharp break in river profile just above Kuala Kubu had intensified the degree of silting, but mining in the upper courses of the river and its tributaries is thought to have been the chief cause of the burying of the town. Much effort is being expended to protect other towns from the same fate. In Pahang, for instance, the Bentong Silt Retention Works are intended to retain tailings from the tin mines in the hills above the town of Bentong.[4]

Along the Malayan coast, the silting of river mouths is common. Bruas, situated on the estuary of the Dindings River, has for this reason declined into an inland village of little importance. Malacca has suffered similarly, otherwise "there appears but little

1. J. S. Simmons and others, *Global Epidemiology*, Vol. 1 (London, 1944), p. 156.
2. For a study of resettlement in Malaya, see E. H. G. Dobby, "Recent Settlement Changes in South Malaya", *Malayan Journal of Tropical Geography*, Vol. 1 (October, 1953), pp. 1-8.
3. "Baring soil of its mantle of natural vegetation reduces the absorption rate of a soil profile for water, and under higher rain intensities surficial run-off is increased over that from a soil covered with vegetation and its ground litter". W. C. Lowdermilk, "Studies in the Role of Forest Vegetation in Erosion Control and Water Conversation", *Proceedings of the Fifth Pacific Science Congress: Canada, 1953*, Vol. 5 (Toronto, 1934), p. 987.
4. Dato' Abu Samah bin Haji Ali, *State of Pahang Annual Report for the year 1949* (Kuala Lumpur, 1951), p. 51.

reason why the former queen of these shores should now sit brooding over her ancient fame".[1] Coastal erosion has also affected settlements. At Pontian Kechil, on the west coast of Johore, some 200 yards of mangrove were cleared from the coast in 1951. After thirteen months the coast had been eroded to a distance of thirty-four yards inland. The danger to Pontian is now imminent and an embankment scheme, costing one million dollars, has been recommended to save the town.[2]

Climate and Settlement

The seasonal fluctuation of rainfall in Malaya, though slight, provides the climatic variable of greatest human significance. Its influence is reflected in the flowering of many trees, so that there are usually two fruit seasons each year. The times of padi planting are fixed in accordance with the rainfall, and where people are primarily padi planters the seasonal rhythm of ploughing, planting and harvesting deeply affects their lives and customs. This is particularly true in northern Malaya where seasonality is most marked. Yet the timing and amount of rainfall from year to year is unreliable. Fig. 3 shows how greatly the amount and incidence of rainfall varied during four consecutive years in Kedah. People are more affected by such variations than by seasonal averages taken over a period of years. Thus, 1949 was a lean year for peasants in Kedah, only 25 per cent of the anticipated 1948–9 crop being realized owing to damage by drought. In the Kota Star and Kuala Muda districts there was a mass exodus of padi planters for employment. A number of them were absorbed by rubber estates in South Kedah and by an irrigation scheme in the Kuala Muda.[3] In Perlis, too, the early onset in November 1948 of the seasonal dry spell caused the complete destruction of approximately 8,380 acres out of a total planted area of 43,430 acres of padi.[4] Seasonal fluctuations in rainfall may also affect the supply of potable water in wells which, because they are fed by surface water, are the more sensitive to variations in rainfall.

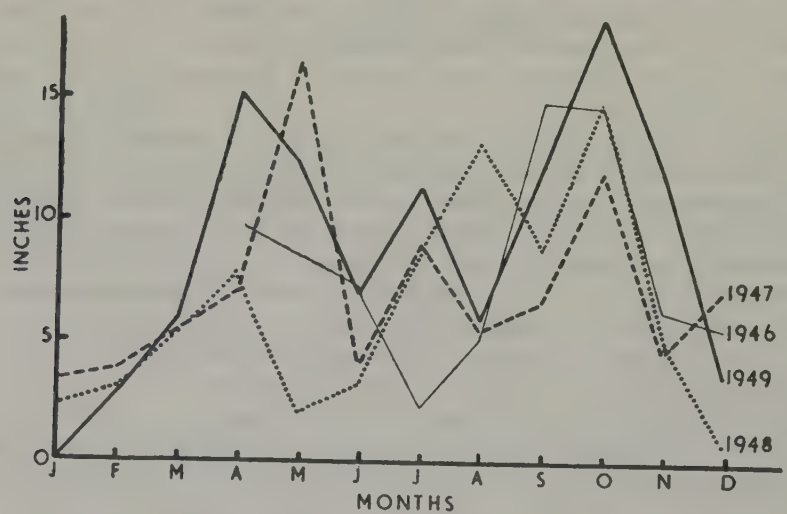


Fig. 3. Rainfall variation at Alor Star, 1946–9. Based on data from H. B. F. Moorhead, "Summaries of Observations", *Malayan Meteorological Service* (1946, –7, –8 and –9).

1. W. W. Skeat and C. O. Blagdon, *Pagan Races of the Malay Peninsula*, Vol. 1 (London, 1906), p. 1.
2. Information supplied by the Director of Forestry, Selangor.
3. Tunku Ismail bin Tunku Yahya, op. cit., p. 23.
4. Raja Haji Ahmad bin Raja Endut, *State of Perlis Annual Report for the year 1949* (Alor Star, 1950), p. 3.

Movement to fetch water during the drier parts of the year is a common feature of rural life in Malaya.

Although diurnal temperature variations are not great in Malaya, they are of more human significance than the slight seasonal changes in temperature. The occurrence of a cool night or day, for instance, is of more human interest than the relative coolness of a season or period. The diurnal range varies with latitude and distance from the coast. Whereas Kuala Lumpur in June has a mean diurnal range of 20° F., in Singapore the range is 11° F.; while the mean minimum temperature for June in Kuala Lumpur is 72° F., that of Singapore is 77° F. Little significance attaches to the isolated areas of high altitude; there are in Malaya no areas of white or other permanent settlement dependent upon the ameliorating affects of altitude, though there are hill stations, notably at Fraser's Hill and Cameron Highlands, where temperatures are reduced by 12 or 15° F.

The enervating effects of the Malayan climate are easy to exaggerate; it is difficult, for instance, to agree with the subjective observation that "the characteristics of all Malayans show very clearly the effects of geographic control. Physically, mentally and morally they are the product of a marine-equatorial climate. Their mental outlook and philosophy, no less than their physique and mode of life, reflect an enervating climate, a circumscribed horizon and a bounteousness of nature which minimizes the necessity of effort".[1] Little data can yet be added to a study made in Singapore in 1919 on the effects of small hills and local air movement on body temperature and comfort.[2] Innumerable observations of a subjective nature could be advanced to indicate that small differences in siting and aspect produce appreciable differences in body temperature and comfort. But a quantitative statement must await integrated research on physiological climatology in the area.

Certainly the Malayan climate is an uncomfortable one,[3] but winds and local breezes are usually present to assist the cooling effects of sweat evaporating from the body; frequent heavy showers, and the processes of acclimitization,[4] all help to make the climate more tolerable than climatic abstractions suggest.

1. C. A. Vlieland, *A Report on the 1931 Census* (London, 1932), p. 8.
2. J. A. Campbell, "Body Temperature and Comfort". *Journal of the Straits Branch of the Royal Asiatic Society*, No. 80 (Singapore, 1919), pp. 63-6.
3. According to Huntington's conclusions on health and physical efficiency, Malaya has a mean daily temperature at least 16° F. above his 64 F. optimum and a relative humidity at least 10 per cent higher than his 75-80 per cent optimum figures. See E. Huntington, *World Power and Evolution* (Newhaven, 1919), Chapter 5.
4. "Permanent dwellers in hot climates in time learn to bear without distress conditions which at first are almost unbearable. In part this is due to the sweat glands being trained to function readily". See D. Brunt, "The Reactions of the Human Body to its Physical Environment", *Quarterly Journal of the Royal Meteorological Society*, Vol. 69 (London, 1943), p 111.

THE RICE PROBLEM

By D. H. GRIST

THE PROBLEM of rice is to produce sufficient to feed the people who rely on this cereal for their principal food. This is perhaps an over-simplified statement of a complex subject and needs amplification. Rice enters into the diet of about half the world's population, including countless millions in Asia who subsist almost entirely on it. Before the last war supplies were barely sufficient to meet the demand at a rather sub-standard level of existence, and in most parts of Asia there was a set-back to production during the war. Recovery, owing largely to the dire necessity of padi planters, has been rapid in some countries, but slow in others where political unrest militates against complete recovery, especially in countries that normally have a large exportable surplus. World production is now at pre-war level, but the rice-eating population has increased at the rate of 10 millions a year, and continues to increase at this rate. To feed this additional population, world production must be increased annually by at least 1·3 million tons.

As rice is the staple food of the great majority of Asians it is of vital importance to the countries concerned with production or consumption. In the extensive rice-producing areas practically the entire population is either directly or indirectly dependent on the success of the crop; outside the rice-producing areas the influence of rice on the economic life of communities and countries may be more subtle but is just as important. Inability to buy rice freely causes disruption of labour conditions, which may affect countries outside the region directly concerned. Wages are largely related to the price at which workers can buy rice; if supplies are short, causing a rise in price—and almost invariably the creation of a black market—increases in wages are demanded and are difficult to resist, resulting in an all-round increase in the cost of living and in the production costs of export foods upon which the country may be dependent. It is, therefore, not sufficient to restore padi cultivation in Asia to its pre-war level; it has become necessary to devise methods of raising production to a higher level to ensure supplies adequate to keep pace with the ever-growing population of rice-eaters in the East. This is mainly an Asian problem, since the people of Asia are not only the largest consumers of rice but also the largest producers. Seventy-five per cent of total world exports of rice are consumed in Asia, while 90 per cent of world production is grown on that continent.

The immediate necessity for larger supplies may be met by increasing the area under the crop and by increased yields. If the price of rice is maintained at a high level the area may be expected to increase in many countries, the chief deterrent to development being the high cost of bringing new land into cultivation. Improvements in yield may be achieved by better drainage and irrigation, more effective control of pests, the enrichment of the land and by improving padi varieties.

DRAINAGE AND IRRIGATION

Successful cultivation of padi depends on adequate inundation of the field during the greater part of the growing period of the plant, and efficient drainage of excess water whenever desirable. Supply and control of water is the most important aspect of padi cultivation; with an adequate and well-controlled water supply the crop will grow

successfully in a wide range of soils and climates. The quantity of water required depends on such factors as field evaporation, seepage, preparation of the land and initial flooding; while the conditions having an important effect on these factors are climate, characteristics of the soil, length of the irrigation period, ground water-table, method of planting, yield and method of irrigation. Yield, in fact, depends in no small measure on the quality of irrigation water.

Irrigation schemes may have any of the following objects in view:—the replacement of primitive means of raising water by modern and permanent works, the construction of permanent works for irrigating new areas and the planning of drainage schemes. Drainage is often more important than irrigating and many areas have been improved by the adoption of drainage schemes. The prerequisite of efficient and economic padi cultivation is adequate control of drainage and irrigation throughout the season. The system should be based not on the average rainfall of the area, but should be designed to supply adequate water during seasonal shortages and to drain sufficiently rapidly in periods of excessive rain.

Drainage and irrigation schemes are likely to prove expensive and there is little likelihood of the capital cost being met by cultivators. Many improvements in Asia have been carried out by governments, and cultivators then called upon to share with government the capital cost and to meet upkeep charges by means of a water-rate. This is usually paid willingly, for cultivators appreciate the fact that they obtain higher yields as a result of improved drainage and irrigation.

Varieties

There are an enormous number of padi varieties, and the variation of characteristics exhibited in them enables the crop to be successfully grown over a wide range of climatic and cultural conditions—on dry land, in arid conditions with irrigation, in deep and undrained swamps and in varying depths of water. The type of padi favoured depends on climatic and cultural conditions, and whether the rice is destined for export or local consumption. Racial preferences are very pronounced: in some countries, for instance, a long-grained, hard rice is favoured, while in others the demand is for a short-grained, semi-glutinous rice. There is no hard and fast division between varieties that grow in water and those that grow on dry ground. There are many varieties of irrigated padi that will not tolerate dry conditions and *vice versa*, but there are also many varieties that will flourish under wet or dry soil conditions. Over vast areas in Asia the varieties cultivated are so mixed that a marked improvement in yield can be obtained in two or three seasons by field selection based upon a single character. In some instances, yields have been increased by as much as twenty-five per cent by the application of this method.

The production of new varieties by hybridization will in the long run give the best results, since not only can this method provide higher-yielding types, but it can be applied to the elimination or reduction of losses from such causes as lodging, and resistance to attacks by pests and diseases. This, however, is long-term work of a very laborious nature, demanding a high degree of skill and much more precise knowledge of the characters of existing varieties than is at present available. Under field conditions, selected strains tend to become mixed with seed from other sources; for this and other reasons, fresh seed must be supplied to growers periodically and this necessitates continuous effort to enable these to be produced and distributed. Yet despite the difficulties

in breeding and distributing improved varieties, such work is likely to prove amply rewarding.

Present interest is centred on two sub-species of padi, *indica* and *japonica*. The former is grown throughout tropical countries, while the latter is more suited to cultivation in sub-tropical latitudes. *Indica* varieties are very tolerant of infertile soils and extreme tropical conditions, but their response to fertilizers is limited. On the other hand, *japonica* varieties are capable of producing very heavy crops, are long-strawed, resistant to the shedding of grain and possess a great capacity for responding to fertilizers. *Japonica* varieties grown under tropical conditions cannot be made to produce the same favourable results as in the sub-tropics.

The need of hybridization is, therefore, evident in order to produce varieties of padi combining the high fertilizer-response of *japonica* types with the hardiness and adaptation to tropical conditions characteristic of *indica* varieties. This hybridization work on *indica* and *japonica* types is being carried out in India under two separate projects. The success of this work will result in the cultivation of new varieties, suited to tropical conditions yet having appreciably higher yields than varieties at present employed in these regions.

Although non-irrigated or "dry" padi is the oldest form of cultivation, it has received less attention than it deserves both from cultivators and investigators. The irresponsible opening up of hilly land for this cultivation, and consequent serious erosion, has been frequent and is to be deprecated, but it is possible to develop hill-land without incurring such damage to the soil. Except in times of economic depression or of failure of the irrigated crop, dry padi cultivation is little practised in Asia. In South America, however, it has made considerable headway. The main advantages of dry-land cultivation are that land with insufficient water-supply for wet padi can be utilized, there is no heavy cost of drainage and irrigation, rotational cropping systems can be introduced and mechanized production is possible.

Pests and Diseases

Padi is subject to insect pests at every stage of its growth, and the losses from this cause are enormous and largely preventable. Further losses of the crop are caused by faulty storage conditions. It is probable that the new and very potent insecticides now on the market may prove of value against certain pests in the field which hitherto have been difficult to control, but good cultural systems and control of irrigation will remain among the most efficient methods of control over many of the pests. It is possible that complete control over field and store pests would increase the world crop from five to ten per cent.

Loss of crop through diseases is often overlooked or considered as negligible. But the crop is liable to many diseases, any one of which may suddenly occasion widespread damage. The urgent necessity of increasing the production of rice by all means directs attention anew to the part played by diseases in lowering yield. Knowledge of the diseases and early diagnosis may obviate preventable losses, while in the prevention and early treatment of diseases, improved cultural methods and better water control will be found of great importance.

Cultivation

The systems of cultivation practised in the East have much to recommend them. They have been devised in the light of practical experience over many generations, and usually succeed in overcoming local difficulties. But they demand the expenditure of

much labour, which is perhaps of little account where labour is plentiful and therefore cheap; but where padi growing must be considered as an economic proposition rather than a family tradition, methods must frequently be modified, or new systems devised. Thus, while mechanization of padi cultivation may not usually improve on the time-honoured hand cultivation, it may prove more economic. Its adoption will, in many cases, enable larger areas to be developed, especially in regions where labour is scarce, while it also enables advantage to be taken of favourable weather conditions. Mechanized cultivation has come to stay, but it is more suited to large areas of flat land than to situations where divisions in the field are small and numerous, and where there are many owners of small areas of land.

In many countries, technical difficulties are experienced in mechanizing the operations of padi cultivation. This is mainly due to the use of implements devised primarily for the cultivation of dry-land crops and unsuited to the conditions peculiar to padi cultivation. Further research on the adaptation of machinery for padi cultivation is therefore necessary. Successful mechanization of padi cultivation demands highly efficient control of an adequate supply of irrigable water. Any attempt to mechanize padi cultivation without first being assured of complete water control at all times is doomed to failure.

Manuring

The three most important plant-food requirements of padi are nitrogen, phosphorus and potassium. The crop receives part of its fertilizer requirement in solution in the irrigation water. It depends for its nitrogen upon the decomposition of organic matter under anaerobic conditions and, especially in the early stages of growth, takes up its nitrogen in the form of ammonia. Padi soils have the power to fix nitrogen from the air, probably through the agency of azotobacter in association with algae in the presence of growing plant roots. Apart from phosphates brought in solution in irrigation water there is no natural means of increase of this element in padi-fields, and as the plant removes considerable quantities from the soil, it may be anticipated that the crop will respond to applications of phosphates. Manuring with phosphates frequently gives increased yields, but in many other cases it has failed to show any response.

Potash is less frequently required on padi soils, probably because such soils are usually of a heavy nature and contain adequate quantities. Iron, manganese, boron, copper and zinc are essential in minute quantities to enable the plant to absorb nitrogen, phosphates and potash, and these trace-elements may profoundly affect the development of the plant at all stages of growth. While minute quantities of these trace-elements have a favourable effect on growth, maturation and yield, larger amounts are extremely toxic to the plant. Knowledge on this subject is at present very incomplete.

It is usually assumed that because padi is grown continuously on the same land it is depleting the soil of plant foods and that therefore the land requires fertilizing. This, however, is not invariably the case; frequently the application of fertilizer results in little or no increase of crop. Admittedly, in a great number of instances a very material increase of crop results from the use of fertilizers, especially with sulphate of ammonia. Numerous manurial experiments have been carried out in many countries; the results stress the fact that throughout practically all Asia fertilizers will materially increase yield, but the increased yield is not always economic.

The general trend of manurial experiments has led to the conclusion that organic matter is of supreme importance in padi growth, fertilization with artificials being subsidiary, or at least complimentary to organic matter. The value of fertilizers has been

clearly proved, but advantage should be taken of their value when applied in addition to, and not instead of, organic matter. The time and method of application of both organic and inorganic manures may well be factors of first importance in manuring padi. This is being widely investigated at the present time; the results may possibly lead to reconsideration of all aspects of manuring.

The system of rotating padi with other crops is intimately connected with soils and manuring. Inadequate control of irrigation in many parts of Asian padi regions, and also the very stiff clay soil, militates against the development of crop rotation. Rotation of padi with other crops is, however, usual in many countries, including the United States of America, New South Wales, Italy and Portugal, and in most of these areas, yields are exceptionally high. Perhaps the most successful of rotations are those that include a period of temporary pasture on which cattle are successfully raised. The extension of this system in padi regions may hold great possibilities, as it would enable animal husbandry to be incorporated into a rice economy under tropical conditions.

Wastage of Rice

Rice is not a complete food, but it has a very high nutritive value, second only to wheat among the cereals. Unfortunately, many of these nutrients—the proteins, fats and water-soluble vitamins of the B-complex—are eliminated in the process of milling and cooking. Many deficiency diseases common in Asia are preventable by such means as improved milling, parboiling and cooking rice whereby the vitamins, in particular, are retained in the grain when eaten.

Losses of nutrients resulting from milling a highly polished rice are very considerable. Proteins, fats, vitamins and minerals are present in greater quantities in the germ and outer layers of the grain than in the starchy endosperm. In milling, most of these nutrients are removed in the bran. The removal in milling of the protecting pericarp also facilitates the extraction of soluble substances from the aleurone layer of the grain during washing immediately before cooking for consumption. If all rice-eaters would accept parboiled rice instead of white rice, subject the grain to less vigorous washing before cooking, and cook in closed containers using the minimum quantity of water, much of the nutrients of the grain would be retained for the benefit of the consumer's health.

Beri-beri is a well-known deficiency disease caused by eating highly polished rice. Research has clearly demonstrated the anti-beri-beri properties of under-milled rice. The consumption of rice not deprived of its outer layers will prevent the disease, while a diet including the "polishings" discarded in the milling process of removing the outer layers will effect a cure of the disease provided it is not in a too advanced stage.

The prejudice of rice-eaters to a diet having a different flavour or appearance from that to which they are accustomed is very real. Recent developments directed to the prevention of loss in bulk during milling, the retention or improvement of nutrients and their protection against loss in storage, preparation for cooking and actual cooking, will only be successful with the co-operation of consumers in accepting a highly nutritious rice rather than an ultra-white rice, bereft of most of its value as a food and consisting of little more than a highly polished piece of starch.

The Possibility of Raising Yields

In the foregoing, an attempt has been made to indicate some of the more important means available for increasing rice production. Taking all the factors into consideration,

it appears possible that improved methods of production might result, in the aggregate, in the production from existing padi areas of a total world crop of 200 million tons of rice, or roughly double the present production. Padi grown under tropical conditions may be incapable of giving the high returns possible in more temperate climates, but yields in most tropical countries still fall short of the amount that should be expected under their particular environmental conditions. They can be raised to a higher level in most countries of Asia by planting improved seed, employing better cultural methods, and by the extended use of artificial and natural manures. It has been estimated that yields might be raised by at least 25 per cent by planting improved seed. Further very material gain could be expected as a result of improved drainage and irrigation, and also by the prevention of loss through the depredations of pests in the field, mill and store. Taking all these factors into consideration, together with others of less importance, the aggregate increase in crop might easily be of such an order as to justify the present writer's contention, arrived at mainly on theoretical grounds, that the potential yield of padi from the existing world area under this crop might be double that at present obtained.

While the immediate necessity for larger rice supplies may be met by increasing the area and improving yields, it is obvious that production cannot increase indefinitely at the rate of over one million tons a year, so that the ultimate solution of the problem of meeting demand by supply must be by the curtailment of population increase. This solution may develop from improved social and economic conditions of rice producers and consumers, and this in no small measure depends on the consumption of an adequate and highly nutritive diet. Thus, the rôle of rice in the development of rice-eating nations is destined to remain important. It constitutes a justification for the employment of immense capital expenditure for the improvement of existing padi areas, the development of new areas and for research along every avenue which may assist the rice industry.

THE CLIMATE AND CLIMATIC REGIONS OF TAIWAN[1]

By CHENG-SIANG CHEN

1 millimetre = 0·037 inches
1 hectare = 2·471 acres

AMONG THE physical factors conditioning present and potential economic development in Taiwan climate plays an important rôle. In spite of an increasing dependence upon industrial production, the islanders' livelihood is obtained pre-eminently from agriculture. Furthermore, owing to a lack of mineral resources, the greater part of future industrial production must be based upon the utilization of raw materials derived from farm lands.

The climatic conditions of Taiwan are more favourable for plant growth than for human energy. The Island receives more abundant rainfall than does any part of mainland China. With few exceptions, the average temperature of the lowlands remains above 15° C throughout the year, and the growing season is essentially continuous for most crops. This means that multiple cropping is possible, with the result that the effective area of cultivated land is greatly extended. Another climatic advantage accrues from the Island's transitional position between temperate and tropical latitudes, which affords a wide variety of crop choices.

Although Taiwan is climatically favoured in a number of ways there are still some handicaps: (1) On the south-western coastal plain the winter half of the year is marked by extended periods without rain. Each year dry spells of two, three or even four months' duration are reported from various localities. (2) The north-eastern sector of the island suffers from excessive rainfall and cloudiness in winter. (3) Rainfall of great intensity comes with violent summer thunderstorms in all parts of the island, resulting in severe hill-side erosion, overloading of streams with débris, and occasional damaging floods in the lowlands. Losses are intensified when heavy rains are accompanied by destructive typhoons, but although these may inflict severe damage on crops and buildings, their occurrence is irregular and infrequent. On the other hand, the strong and steady north-east monsoon of winter generates perennial climatic troubles. Especially along the flat western coast these winds deposit salt spray, desiccate soils and plants, and cause the landward encroachment of sand dunes.

(1) MONSOONS AND THE RAINY SEASON

The north-east and south-west monsoons are the main factors that control the climate of the island. These two monsoons differ from each other not only in their directions but also in their natures, intensities and the times of their occurrence. The north-east monsoon prevails from late October to late March, thus lasting about five months and bringing the rainy season to the windward side of north-east Taiwan. Since the north-east monsoon comes from the same direction as the north-east trade wind, its force is very strong, especially in the northern part of Taiwan. For example, the mean wind velocity is 3·9 metres per second at Taipei in November, and 4·0 metres per second at Hsinchu in November. Because of the gustiness of the winter monsoon, crops have to be carefully protected by wind-breaks.

1. Unless it is stated to the contrary, data used in this paper are abstracted from the unpublished records of the Provincial Weather Bureau, Taipei.

Over the sea off north Taiwan and over the Strait of Taiwan the winter monsoon blows even more strongly. The mean annual wind velocity at Pengchiayu is 7·3 metres per second, and the mean wind velocity at the same place in December is 8·6 metres per second. For another example, the annual mean wind velocity at Penghu (the Pescadores) is 6·4 metres per second, while the mean wind velocity in December reaches as much as 9·1 metres per second. During the winter months, gales (i.e. winds stronger than 10 metres per second) sweep over the flat Pescadores almost every day. The annual total of days on which gales are recorded in the Pescadores is 137, of which 113 occur in the winter half of the year. The north-east monsoon is so strong in winter that vessels sailing through the Strait of Taiwan often find it difficult to steer northward in this season.

The south-west monsoon, on the other hand, beginning in early May and ceasing in late September, lasts about five months. During this period south-west winds predominate, though their force is by no means as strong as that of the north-east monsoon. The mean annual wind velocity at Hengchun is 4·1 metres per second, while the wind velocity in the four-month period from May to August averages only 2·8 metres per second. At Keelung, the mean annual wind velocity is 3·3 metres per second, yet the mean wind velocity in the four months from May to August is only 2·6 metres per second. During the season of the south-west monsoon, south Taiwan often has rainy weather, while the northern part, in the shadow of the mountain range running between Suio and Fungyun, has fine weather.

TABLE 1: MEAN MONTHLY WIND VELOCITY (in metres per second)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Ilan	1·6	1·6	1·6	1·5	1·3	1·3	1·9	1·7	1·8	1·7	1·5	1·5	1·6
Keelung	4·0	3·8	3·3	2·7	2·4	2·3	2·9	2·9	3·3	3·7	4·1	4·0	3·3
Taipei	3·4	3·3	3·5	3·1	2·8	2·2	2·5	2·7	3·1	3·7	3·9	3·7	3·2
Hsinchu	3·4	3·4	2·8	2·3	2·3	2·8	2·7	2·2	2·5	3·8	4·0	3·8	3·0
Taichung	2·1	2·1	1·9	1·6	1·4	1·5	1·5	1·4	1·5	1·8	1·9	2·0	1·7
Tainan	3·8	3·8	3·4	2·8	2·5	2·6	2·6	2·5	2·5	2·6	3·1	3·5	3·0
Hengchun ..	5·2	4·7	4·5	3·6	3·0	2·7	2·8	2·8	3·0	4·9	6·0	6·1	4·1
Taitung	3·7	3·6	3·3	2·8	2·5	2·3	2·4	2·3	2·7	3·5	3·8	3·7	3·1
Hualien	3·1	2·9	2·9	2·5	2·2	2·2	2·3	2·2	2·4	2·7	2·9	3·1	2·6
Penghu	8·6	8·0	6·9	5·4	4·4	4·2	3·8	3·9	5·3	8·3	9·0	9·1	6·4
Mt. Ali	1·8	2·0	2·0	1·9	1·7	1·9	1·8	1·7	1·6	1·4	1·4	1·5	1·7

As the range of temperature in this tropical area is small, the importance of the rainy season for agriculture is quite obvious. The chief influence of the monsoon on land use in Taiwan lies in its control over the lengths of the rainy seasons in various places. These are tabulated in Table 2. After the close of the rainy season, the rainfall diminishes until finally the dry season comes. On the basis of a dry season beginning

when the average rainfall over a five-day period is less than 10 mm., there is actually no dry season in north-east Taiwan, while the dry season in the south-west lasts for more than 150 days.

TABLE 2: RAINY AND DRY SEASONS IN TAIWAN

Locality	RAINY SEASON (>20mm. in 5 days)			DRY SEASON (<10mm. in 5 days)		
	Beginning	Ending	Length (in days)	Beginning	Ending	Length (in days)
Ilan	late May	early May	350	—	—	—
Taipei	late Jan.	early Oct.	257	early Nov.	early Nov.	10
Taichung ..	middle Mar.	middle Sept.	192	early Oct.	late Jan.	115
Tainan	middle May	middle Sept.	131	early Oct.	middle Mar.	170
Hengchun ..	early May	middle Oct.	162	late Oct.	early May	190
Taitung ..	early May	middle Oct.	162	early Nov.	middle Feb.	110
Penghu	middle May	middle Sept.	121	late Sept.	middle Mar.	180

If the monsoon is very strong, it does much harm to field crops. The Taiwan observatories recorded 7,205 gales in the twenty-year period from 1917 to 1936, and most of the destructive ones occurred during the north-east monsoon. Along the west coast of Taiwan, before the setting up of wind-breaks, the yield per hectare of the second crop of padi was often only half that of the first. In spite of this protection, the yield of padi is still greatly reduced when the monsoon is too strong, as is that of sugar-cane. Generally speaking, a wind of velocity greater than 15 metres per second is strong enough to break the leaves of the cane, which considerably reduces the sugar content. In the ten years from 1926 to 1935, gales did serious damage to the crops in Taiwan twenty-seven times, with the losses amounting to 3,975,000 yen[1] in an affected area totalling 144,000 hectares. Previously, windbreaks planted by the Japanese as a means of reducing damage from gales achieved some success. In Hsinchu district, for instance, second-crop padi which is within a distance twenty times the height of the trees planted exceeds, on the average, by 30 per cent the crop of the near-by fields which have no protection.

(2) RAINFALL

Taiwan has abundant rainfall. As measured by more than 200 stations on the main island and adjacent islets, the average annual rainfall is 2,580 mm., while in any year it may reach more than 5,000 mm. The station at Hosoulio has had for the past thirty-eight years an average annual rainfall of 6,572 mm. with a recorded maximum of 8,408 mm. in 1912.

The places with least rain in Taiwan are on the west coast (Fig. 1B). Chutan, in the centre of this coast, for instance, has had for the past thirty-two years an average rainfall of only 1,200 mm. Its minimum annual rainfall is 690 mm. Among the dependent islets, Yuwontao in the Pescadores is the least rainy place. It has had for the past

1. One yen was at that time approximately equivalent to £0/1/5 sterling or U.S. $0·32.

forty-four years an annual mean of 920 mm., while the minimum annual rainfall is as low as 413 mm. There are four factors that contribute to the dryness of the Pescadores. First, they are low and flat. Second, the winds are often very strong; third, the summer months are rather cool; and fourth they are situated in a rain-shadow.

TABLE 3: RAINFALL OF TAIWAN (in mm.)

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Ilan	152	149	129	125	214	245	157	188	386	399	358	245	2,747
Keelung ..	307	293	298	217	261	287	137	167	250	247	269	309	3,042
Taipei	90	136	174	168	219	316	234	285	221	122	64	74	2,103
Hsinchu ..	71	134	158	205	246	397	146	180	104	34	36	54	1,765
Taichung ..	34	67	107	128	236	394	292	325	134	22	17	29	1,785
Tainan	19	33	47	70	185	390	438	422	164	35	17	19	1,839
Hengchun ..	21	28	23	45	173	417	539	539	292	142	54	19	2,292
Taitung	36	43	60	75	165	233	339	293	300	177	81	41	1,843
Hualien	59	83	107	114	202	195	267	234	301	262	136	72	2,032
Penghu	24	37	65	80	110	174	189	172	106	33	21	23	1,034
Mt. Ali.	68	126	191	267	557	885	807	784	447	131	58	95	4,416

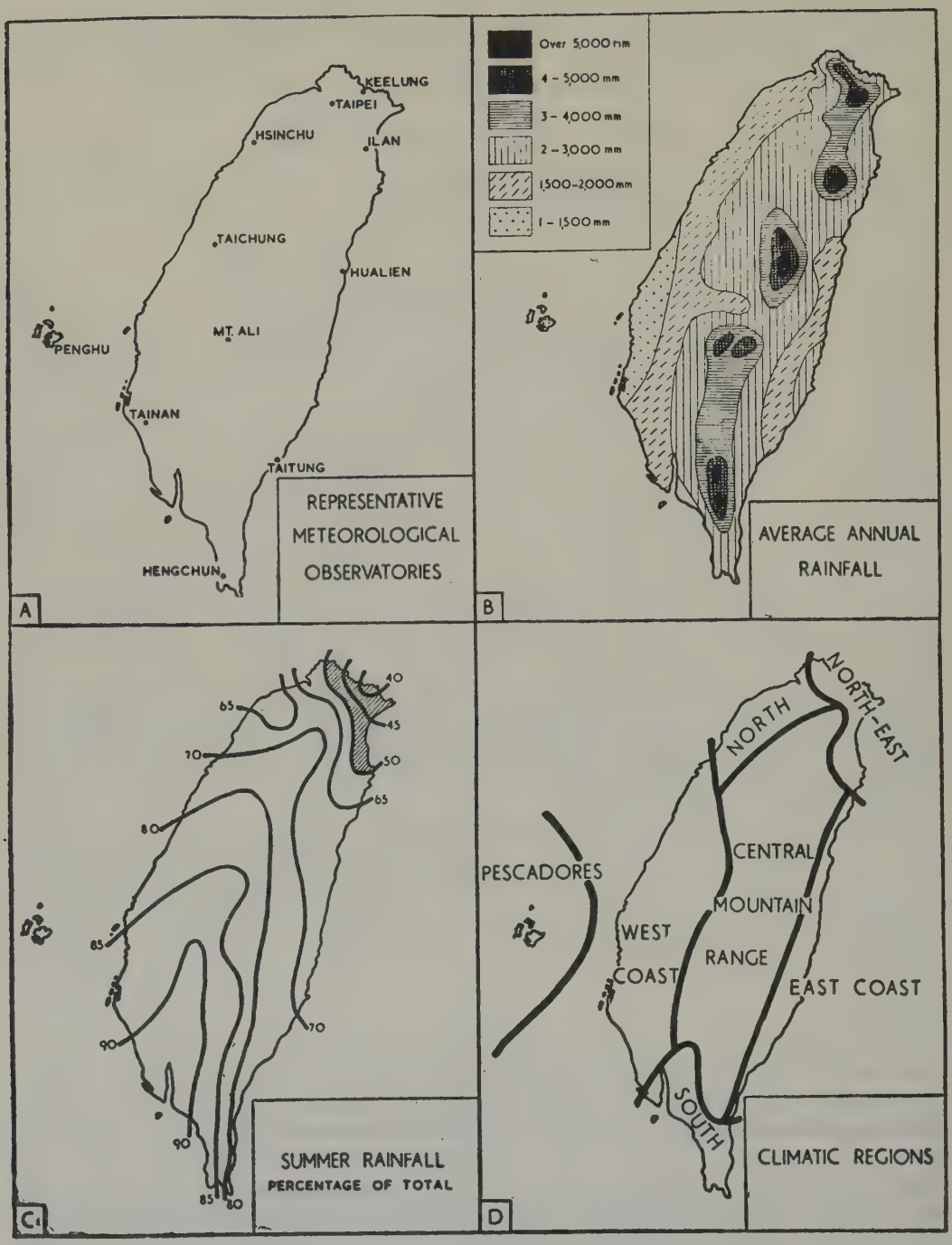
By comparing a relief map with a rain chart of Taiwan,[1] it becomes apparent that topography exerts a very strong control over the distribution of rainfall on the island. On the western plain, rainfall increases in proportion to the gradual rising of the land between the seashore and the interior.

TABLE 4: CONTROL OF RAINFALL BY RELIEF

	Pekang	Chuchi	Yiuyenlin	Mt. Ali	Mt. Yu
Distance from sea (km.)	17	43	56	70	85
Elevation (metres)	9	129	1,060	2,406	3,850
Annual Rainfall (mm.)	1,493	2,555	3,045	4,416	3,039

Owing to the different directions from which the winter and summer monsoons approach the high mountain barrier, the seasonal distribution of rainfall in north Taiwan is quite different from that in the south. In the north rainfall is distributed fairly evenly throughout the year (Fig. 1c), and in the north-east sector it is more abundant in the winter half of the year than in the summer months. The region lying to the south of latitude 23° N is dry in the winter months, for it is on the leeward side of the mountains

1. E.g. C. S. Chen, *Atlas of Land Utilization in Taiwan: Research Report No. 15 of the Institute of Agricultural Geography* (Taipei, 1950). See also "Land Utilization in Formosa", *The Geographical Review* (New York, 1951), pp. 438-68.


KEELUNG
TAIPEI
HSINCHU
ILAN
TAICHUNG
HUALIEN
MT. ALI
PENGHU
TAINAN
TAITUNG
HENGCHUN
REPRESENTATIVE METEOROLOGICAL OBSERVATORIES
A
Over 5,000 mm
4 – 5,000 mm
3 – 4,000 mm
2 – 3,000 mm
1,500–2,000 mm
1 – 1,500 mm
AVERAGE ANNUAL RAINFALL
B
40
45
50
65
70
80
85
90
SUMMER RAINFALL
PERCENTAGE OF TOTAL
C
NORTH
NORTH-EAST
CENTRAL MOUNTAIN RANGE
PESCADORES
WEST COAST
EAST COAST
SOUTH
CLIMATIC REGIONS
D

during the north-east monsoon. But in summer, because it faces the south-west monsoon and because the intensity of the rainfall is very high, precipitation is much greater than in winter. The farther the region extends to the south, the more apparent does the concentration of rainfall in the summer half-year become.

For convenience of calculation, the months from April to September may be regarded as the summer period, and the months from October to March as the winter period. In accordance with this, the shaded portion of Fig. 1c is the area where rainfall is more abundant in the winter half-year than in the summer. The line denoting 50 per cent on the same map is the dividing line between the winter rainy region and the summer rainy region. North of this line, more than half the total annual rainfall comes in winter, and south of this line, the summer rainfall exceeds half the annual total. The farther the region extends to the south, the greater becomes the difference between the amount of summer rainfall and that of the winter. Taking Keelung as representative of the northern sector and Pintung of the south, the following comparison emerges.

TABLE 5: SEASONAL DISTRIBUTION OF RAINFALL

	KEELUNG		PINTUNG	
	Winter (Oct to Mar.).	Summer (Apr. to Sept.)	Winter (Oct. to Mar.)	Summer (Apr. to Sept.)
Rainfall (mm.)	1723	1320	188	2220
Percentage of Annual Rainfall ..	56·6	43·4	7·8	92·2
Rainfall of wettest month (mm.) ..	Dec. (309)	June (287)	Oct. (68)	Aug. (616)
Rainfall of driest month (mm.) ..	Oct. (247)	July (137)	Dec. (13)	Apl. (67)

Fig. 1. (opposite) A. Representative meteorological observatories on the Island of Taiwan. The elevations of these stations and the periods during which they have been operating are as follows:—

Station	Height above S.L. (in metres)	Records begin
Keelung	32	1903
Taipei	8	1897
Hsinchu	32·8	1938
Ilan	7·4	1936
Taichung	77·1	1897
Hualien	17·6	1911
Mt. Ali.	2,406	1934
Penghu	9·4	1897
Tainan	12·7	1897
Taitung	8·9	1901
Hengchun	22·3	1897

B. Taiwan: average annual rainfall.
C. Taiwan: summer rainfall as a percentage of the annual total.
D. Taiwan: climatic regions.

Variation of rainfall from the mean also increases from north to south. In the north-east corner annual variations are generally around 15 per cent, e.g., at Ilan the mean variation is 14·8 per cent. The central north has a variation of about 20 per cent, e.g. Taipei 20·7 per cent and Taichung 21·7 per cent. From Taichung southwards variation increases rapidly to 28·5 per cent at Tainan; 34·2 per cent at Kaohsiung; 34·4 per cent at Hengchun. On the east coast of the Island, Hualien has a variation of 30 per cent; Taitung 38·6 per cent. The Pescadores and Mt. Ali have a variation of 22·9 per cent and 17·6 per cent respectively.[1]

For the fifty-year period from 1897–1946, Taipei had a mean annual rainfall of 2,111 mm., with a maximum annual rainfall of as much as 2,739 mm. and a minimum of only 1,499 mm. Taichung had a mean annual rainfall of 1,783 mm., a maximum of 2,837 mm., and a minimum of 1,097 mm. Tainan had a maximum annual rainfall of 2,926 mm. and a minimum of 685 mm., which was less than one half of the mean annual rainfall.

The summer rainfall of Taiwan comes chiefly in the form of warm thunder-showers and typhoons. Thunder-showers are common in the summer months, especially in June, July and August, when they frequently occur on successive afternoons. Typhoons also occur throughout the summer, but especially in July, August and September. As typhoons are often accompanied by cloudbursts, some mountain slopes to windward receive as much as 1,000 mm. of rain in twenty-four hours. For example, the rainfall was 1,164 mm. on 30th August, 1940 on Mt. Ali; 1,050 mm. on 3rd September, 1945 at Chuchi; and 1,034 mm. on the 31st August, 1911 at Fenchifu.

Even though the summer half-year is usually said to begin in April, the increase in rainfall during this month is not very large, but it is subject to great variation in amount from year to year. During the summer period the rainiest months are those from June to September. After September, if no typhoon passes over the Island, the rainfall shows a sharp decrease.

In all the winter months in Taiwan the north-eastern sector is very rainy. The strong north-east monsoon, after sweeping over the ocean, has absorbed abundant moisture which is easily precipitated over the land. However, the rainy places in the winter half-year in Taiwan are restricted to a small area in the north-east corner, where it often rains for weeks, and sometimes even for one or two months. In the period 1905–45, as recorded by 199 rain gauges on the Island, there were altogether 321 occasions on which rain lasted for more than thirty days, and thirty-two instances when it lasted for more than fifty days. In that section of the east coast between Hualien and Taitung which is parallel to the path of the north-east monsoon, the amount of rainfall, despite the gloomy weather, is not great in this season.

The greater part of south Taiwan has very little rain during the winter half of the year when, on account of the mountain barrier, it receives only 20 per cent of its yearly total while the south-west corner has even less. For example, Pintung receives only 10 per cent of its annual total. Frequently, there is no rain at all for a month or more. Sometimes the prolonged drought may last even for 100 days, so that in strong winds dust and sand are whipped up from the drying ground and diffused through the atmosphere like haze. For many years before the Japanese occupation (1895) irrigation works were highly developed to combat the deficiency of winter rain, and today they are being multiplied and improved. But in the unirrigated districts along the west coast, where water supply is difficult, the cultivation of padi cannot be carried on unless the rain

1. These figures are from a record covering the twenty years 1927-46.

comes, and such activity is always subject to delay. Periods of 150 days or more in which rain was totally absent, or at most, present in very small amounts, have been recorded at the following places.

TABLE 6: NOTABLE DROUGHTS

Year	Station	Began	Ended	Total period (days)
1911	Pingtung	Oct. 2	March 5	155
1911	Fungshan	Oct. 4	March 4	152
1919	Chishan	Oct. 14	April 25	194
1925	Chishan	Sept. 28	Feb. 25	151
1929	Changhua	Aug. 8	Jan. 24	161
1938	Kueitung	Oct. 6	March 11	157
1939	Tapang	Oct. 11	March 9	151
1939	Tungshih	Oct. 1	March 8	160
1942	Fangshan	Oct. 22	March 28	158

(3) TEMPERATURE

Partly as a result of its low latitude and of its being surrounded by warm currents, and partly as a result of the winds blowing over warm seas, Taiwan has a warm climate which allows the growth of a perennial vegetation and which also permits of a twice-yearly rice harvest. The cultivation of sugar-cane is extensive and there is a large production of such tropical fruits as the banana and pineapple.

The summer is long and accompanied by intense heat, while the winter is very short and never severely cold. Although the peaks of high mountains are temporarily capped with snow, even in the coldest month frost is very rare on the lowlands. If summer is defined as a period with a temperature of 22°C or more in every five days, then, in the lowlands of Taiwan, summer always lasts more than 200 days, and there is no winter in the real sense of the word.

Throughout the Island the mean monthly temperature reaches 20°C in April and keeps at about this level until November. The period from June to September is the hottest time of the year, when the mean monthly temperature ranges from 26°–28°C. During this period, there is no remarkable temperature variation between the south and the extreme north of the Island. The daily maximum may rise above 30°C and remain so for several weeks. Extreme maximum temperatures in various places in Taiwan are as follows: at Taipei, 38·6°C; Taichung, 39·3°C; Tainan, 37·8°C; Hengchun, 37·1°C; and Penghu, 34·°C.

TABLE 7: THE BEGINNING, ENDING AND LENGTH OF SUMMER

Location	Beginning	Ending	Length (in days)
Taipei	late April	early November	200
Taichung	middle April	early November	215
Tainan	early April	middle November	225
Hengchun	early March	middle December	290

When winter comes, or more accurately, with the arrival of the cool season, the variation of temperature between south and north becomes more apparent. In February, the coldest month for a large part of Taiwan, the mean monthly temperature at Hengchun is 20·5°C; and at Taipei, 14·8°C, showing a difference of 5·7°C. On the average, for every 55 kilometres one moves northwards the mean temperature of the coldest month falls by 1°C.

Colder weather occurs only in the north and there only when that part is subject to persistent rain or when it is influenced by cold air flowing southward from the mainland. The extreme minimum recorded at Taipei is –0·2°C, and at Taichung –1°C. Frost is occasionally seen on the ground in the northern part of the Island. In the fifty years 1897–1946 Taipei had thirty-four frosts, Taichung thirty-one and Tainan only four. However, this possibility of frost is one of the reasons why sugar-cane, banana and pine-apple plantations are limited to the south and centre of the Island.

Since 1895, ice has been seen in the lowlands only once. It happened in Taichung, on the 13th February, 1901, when the temperature fell to –1°C, the lowest point ever recorded in the lowlands of the Island.

The annual range of temperature in Taiwan is nowhere high; lowland stations, from Taipei to Hengchun, have an annual range of only 13·4°C to 7·2°C. But diurnal variations of temperature in Taiwan as a whole are considerable. The diurnal range in the north-east is greater in summer than in winter, but the reverse is true of the south. The maximum mean diurnal range recorded at Taipei in July is 8·9°C, and the minimum mean diurnal range recorded at the same place in February is 6·6°C. On the other hand, the maximum mean diurnal range at Tainan in February is 11·3°C, and the minimum mean diurnal range at the same place in August is 7·7°C.

Table 8: Mean Monthly Temperatures (°C)

Locality	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Ilan	16·0	16·2	18·1	20·8	23·8	26·0	27·6	27·3	26·0	22·7	20·1	17·3	21·8
Keelung	15·6	15·2	16·8	20·2	23·6	26·3	28·0	27·9	26·4	23·4	20·3	17·3	21·8
Taipei	15·2	18·0	17·1	20·7	24·2	26·6	28·2	28·0	26·4	23·1	20·0	16·9	21·8
Hsinchu	15·1	14·9	17·1	20·6	24·5	26·6	28·0	28·0	26·7	23·5	20·6	16·9	21·9
Taichung	15·8	15·8	18·4	22·1	25·3	26·9	27·8	27·5	26·7	23·9	20·7	17·4	22·4
Tainan	17·1	17·2	19·9	23·4	26·4	27·4	27·9	27·6	27·2	24·9	21·8	18·5	23·2
Hengchun ..	20·4	20·6	22·4	24·6	26·6	27·4	27·5	27·3	26·8	25·4	23·5	21·4	24·5
Taitung	19·0	19·1	20·8	23·2	25·4	27·0	27·5	27·3	26·6	24·5	22·3	20·0	23·6
Hualien	17·3	17·5	19·1	21·7	24·2	26·2	27·3	27·1	26·1	23·6	21·3	18·8	22·5
Penghu	16·3	15·9	18·5	22·1	25·2	27·1	28·0	27·9	27·2	24·7	21·7	18·3	22·7
Mt. Ali.	5·9	6·5	8·6	10·6	12·5	13·8	14·1	13·9	13·4	11·5	9·7	7·7	10·7

(4) Typhoons

The island of Taiwan lies in the usual path of the tropical cyclones known in this part of Eastern Asia as typhoons. These are the most destructive of the natural calamities that occur on this agricultural island. A severe typhoon, bringing violent winds and tremendous rainfall, will do heavy damage to field crops. Most of the typhoons originate in the ocean east of the Philippine Islands. They occur mostly in the summer months, especially in July, August and September. During the last fifty-six years the earliest typhoon of the season occurred on the 17th May, 1947 and the latest on the 26th November, 1952. In the same period (1897–1952) there occurred a total of 204 typhoons, distributed throughout the year as follows.

	May	June	July	August	Sept.	Oct.	Nov.
Total typhoons	9	11	54	64	45	18	3
Percentage	4	5	27	31	22	9	2

A large number of typhoons passing the Island of Taiwan move towards the north-west or west-north-west and eventually dissipate themselves over the mainland. Some of them, however, still maintain their vigour, and after changing their course over the continent to a north-easterly direction, traverse the Yellow Sea towards the southern coast of Japan and Korea. A large amount of rain is sometimes brought to the west side of the Taiwan mountain range by the south-westerly winds of a typhoon passing over the north of the Island; while heavy rain is brought to the east coast by north-easterly winds if the typhoon passes over the south.

The available statistics record the following damage from typhoons between 1897 and 1952: a total of 4,814 persons killed and 6,546 wounded, that is, an average of 203 people wounded or killed each year; 224,145 houses totally destroyed and 519,615 damaged, that is, an average of 13,281 damaged or destroyed each year.

The typhoon that struck the Island on 25–26th September, 1946 was the most violent and destructive of all. Barometric pressure at the centre fell to 703 mm. (937 mb.) when it approached the east coast. The mean maximum wind velocity reached 40·3 metres per second and the extreme maximum recorded was as high as 55 metres per second. As a result of this severe storm, great damage was caused over the whole Island; 373,748 houses destroyed, 564,263 hectares of crops and forest damaged, 28,448 animals lost, 154 persons killed and 618 injured.

(5) Climate Regions

Not only do differences of climate exist between south and north Taiwan, but also between east and west, not to mention the central mountainous region, the climate of which is quite different from that of the surrounding lowlands. In order to summarize the climatic elements discussed above and to facilitate the study of climatic influence on crop distributions it is useful to distinguish the following climatic regions, seven in number, and each possessing distinctive characteristics (Fig. 1D).

(i) *North-Eastern Region*

This region is limited to the north-eastern corner of the Island, facing the open sea and backed by a central mountain chain. The main characteristic of the region is that

it has no dry season. Its annual rainfall generally ranges from 2–3,000 mm. There are times when precipitation on the mountain slopes exceeds 4–5,000 mm. Moreover, rainfall is greater in winter than in summer. Humidity and cloudiness are both high, sunshine and evaporation low. The average temperature of the coldest month is above 15°C. and that of the hottest month is about 28°C. The farm land in this region is generally threatened by floods, and, therefore, drainage is more important than irrigation. The chief crop is rice, and there is some prospect of a dairy industry developing.

(ii) *Northern Region*

This hilly area occupies the northern part of the Island. The climate is transitional between that of the north-eastern region and that of the western. Its annual rainfall is between 1,500 mm. and 2,500 mm. Summer rainfall exceeds that of winter, though the latter season is by no means dry. In winter this area, being in the path of the cold air moving southwards from the mainland, is chilly. The mean temperature in the coldest month is below 15°C. Occasionally there is frost or snow.

Along the coastal zone of this region, the winter monsoon is very strong, and crops are commonly protected by wind-breaks. A common saying among the people is that, "Hsinchu is windy and Keelung rainy". The two major cash crops on the hilly lands of this region are tea and citrus fruits. The concentration of these two crops in this area is a consequence of climatic influences and also of topographical limitation.

(iii) *Western Region*

This region, embracing the whole western coastal plain and a hilly belt on its eastern side, produces more than two-thirds of the total rice and sugar of the Island. The climatic features may be briefly summarized as follows: (1) It is the driest part of the Island, with an annual rainfall limited to 1,500 mm. or so; (2) there is a marked concentration of rainfall in summer (80 per cent of the annual total); (3) the winter is very dry, with a high frequency of prolonged droughts. Irrigation is necessary for farming. The temperature in the coldest month is generally between 16 and 20°C and is thus higher than that of the northern region. If Tainan is taken as representative of this region and Taipei of the northern, then the climatic differences between these two regions can be shown in the following table.

Table 9: The Weather of Tainan and Taipei

Items	Tainan		Taipei	
	January	July	January	July
Clear days	5·6	1·5	2·0	2·6
Cloudy days	8·1	11·1	20·2	10·1
Rainy days	4·9	17·5	16·1	14·2
Relative Humidity (percentage) ..	79·0	83·0	84·0	78·0
Hours of Sunshine	199·0	238·0	89·0	223·0

(iv) *Southern Region*

This region includes the Pintung Plain and the Hengchun Peninsula. As delimited in the north by the 20°C isotherm of the coldest month, it may be regarded as a truly tropical area. It has an annual rainfall ranging from 1,500 mm. to 2,500 mm. Its summer rainfall often comprises more than 90 per cent of the annual total so that the concentration of rainfall in that season is even more remarkable than that of the western region. In areas around Hengchun, the temperatures would be suitable for the growing of certain tropical crops of economic importance such as rubber, but the strong winds, high evaporation and very dry weather in winter, preclude their introduction.

(v) *Eastern Region*

Situated to the east of the central highlands, this narrow region includes the longitudinal valley and Taitung coastal range. The annual rainfall is generally 2,000 mm., and is, therefore, more abundant than that of the west coast in the same latitude. But the concentration of rainfall in summer is not so marked as in the west. The mean temperature in the coldest month is between 16°C and 20°C.

One of the greatest climatic drawbacks of this region is the scarcity of sunshine, the major factor contributing to the extremely low yields per unit area and high losses from insects and disease. According to the records of the last twenty years, for example, sunshine at the Hualien Sugar Refinery averages only 1,252 hours throughout the whole year, which is scarcely half that of the western coastal plains. In the winter period there is especially little sunshine—on the average fifty-six hours in February, or only one-third of that on the western coastal plains.

(vi) *Central Mountain Region*

The central part of Taiwan is a large mountainous area, the climate of which is controlled mainly by its elevation and exposure. There is, however, a great diversity of local climatic conditions. As the altitude increases, temperature normally becomes lower: the mean lapse rates are 0·41–0·53°C per 100 metres in the south, and 0·59–0·62°C per 100 metres in the north.[1] Although snow and frost hardly appear in winter on the lowlands of Taiwan, there is snow for most of the time over the high mountains. Mt. Yu (3,950 metres), the highest peak on the Island has snow from early December. On Mt. Ali the first frost appears on the average on 22nd October and the last on 11th April, with an average period of frost lasting as long as 170 days.

In many parts of this region, average yearly precipitation is over 3,000 mm., and some windward slopes may get more than 4,000 mm. If the climate of Mt. Ali is representative of the western flank of this region, then its homoclime is to be found around Darjeeling on the southern slopes of the Himalayas, a region famous for its black tea. There are also tea plantations on the slopes of Mt. Ali.

Except where it has been burned by aborigines to make small clearings for primitive cultivation, the central mountain area is almost entirely covered by forest. If the principles of soil conservation are not violated, all the land at the foot of the mountains and on the gentler slopes is in the future likely to be appropriated for tea gardens, orchards and dairy farms.

1. C. S. Chen, "The Climate of the Mountain Region of Taiwan", *Institute of Agricultural Geography: Research Report No. 61* (Taipei, 1954).

(vii) *The Pescadores*

The climate of these islands is rather akin to that of the western plain of Taiwan, except that its rainfall is somewhat less (about 1,000 mm., of which 80 per cent or more is concentrated in summer). The characteristic of this island group is windiness, which is a great disadvantage to farmers. The average annual wind velocity at Makung, the capital of the islands, is 6·4 metres per second. During the winter months, when the north-east monsoon prevails, the wind is stronger and may reach 10 metres per second. The annual total of gale days is 137, which severely restricts the planting of crops. It is, for example, impossible to grow rice and sugar-cane in this area. Sea spray is often carried several miles inland by the high winds. Farmers build wind-breaks of stone and coral rock, and plant within the walls sweet potatoes, peanuts, corn and some vegetables.[1] Even the growth of trees is greatly stunted, for if it is higher than the wall, a tree is not safe from the destructive wind. All these factors are sufficient to explain why the Pescadores, in spite of their subtropical, marine location, are still largely desolate.

1. C. S. Chen: "The Pescadores", *The Geographical Review*, Vol. 43, No. 1 (1953), pp. 77-90.

A NEW TOWN IN MALAYA

Petaling Jaya, Kuala Lumpur

By T. A. L. CONCANNON

THE TOWN of Kuala Lumpur is the capital both of the Federation of Malaya and of the State of Selangor, and today has a population of some 300,000 persons included within the Municipal boundary of 22,000 acres.

It is approaching 100 years since the famed Capitan China, Yap Ah Loy, a pioneer Chinese tin-miner, laid the foundations of the present town in what was, on his arrival in 1857, little more than a tiny mining hamlet in a jungle swamp. The site lies in a basin fringed by low hills on the west and east and by the main mountain range of the Peninsula to the north and north-east; it is open towards the south and south-west and most of the fringe land contains rich deposits of tin ore. The original basic economy of the modern town was founded on the mining of this tin, which remains today the most important economic factor in its existence. But with the growth of the rubber industry, the rate of expansion was accelerated and, although in the first years of its life Kuala Lumpur suffered destruction both by disastrous fires and attack by marauding bands, in the early eighteen-nineties a considerable amount of building development had taken place and many permanent buildings were in existence.

A map of the town in 1895 (Fig. 1) shows that the central area had already begun to form, with the traditional eastern shop-house and other commercial premises, while many residences for European officials and business men and local inhabitants had been built in the outlying, cleared jungle areas.[1] At that time fairly considerable parts of the land fringing the township were under cultivation with coffee (a crop that was later to be abandoned), and the remaining land was cultivated with the newly discovered rubber.

By 1900 the population of Kuala Lumpur had risen to 30,000, and by 1910 the figure had reached 45,000. Commercial premises, residential, shop and terraced houses were built on an increasing scale in the years 1905 to 1915; and this period included the construction of the surprisingly large existing railway station, designed in Saracenic style and completed in 1910. The equally large and imposing Government Office block, designed in a similar style, was completed in 1897. By 1920 the population had increased to 80,000, and in 1931 the figure was estimated to be about 110,000. In the years 1925–30 there was an acceleration in development, particularly in the business and commercial central area and the expanding residential areas. It is not without interest here to note that in 1922 the first Government Town Planner was appointed to the then Federated Malay States in the person of C. C. Reade, who appears to have had the advice of the late Dr. Henry Lanchester in the design of some of the major road improvements of that period and in the detailed laying-out of a few of the housing estates, which latter remain today a pleasant feature of the town.

In 1936 the town population had risen to nearly 120,000, and according to the official census had reached 175,000 in 1947, increasing by normal expansion to 200,000 in 1951. By the end of 1951 it has been calculated that the population increased to 220,000, representing a remarkable advance of nearly 100 per cent in approximately

1. See also Chong Seck-chim, "The Development of Kuala Lumpur District", this *Journal*, Vol. 3 (Oct. 1954). Fig. 1, p. 49.

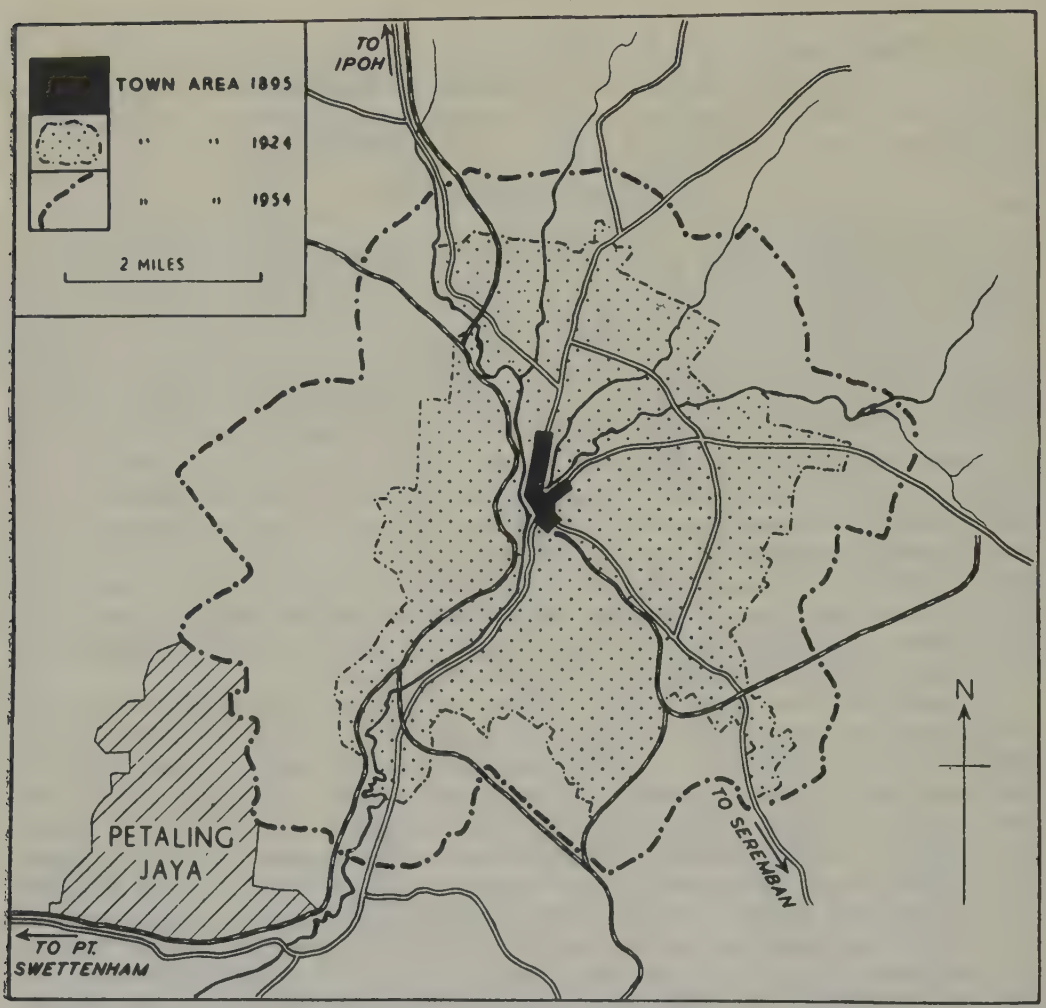


Fig. 1. The areal expansion of Kuala Lumpur, 1895–1954, and the site of the satellite town of Petaling Jaya.

fifteen years. According to the 1947 census this population was composed of Chinese (63·5 per cent), Indians 17·9 per cent), Malays (10·9 per cent), together with small numbers of Eurasians, Europeans and other nationalities making up the remainder.

During the Japanese occupation from 1941–5, permanent building construction was brought almost to a standstill, but a great amount of very temporary building took place on a large scale. In the approved Town Plan prepared before the occupation certain areas had been selected for temporary housing and strict control exercised over construction and layout but, during the occupation, development followed no coherent plan and was largely, if not entirely, uncontrolled.

With the advent of the British Military Administration at the end of the war, erection within the town boundaries of temporary housing and military camps without proper planning direction and advice was unfortunately permitted. When the Town Board (then the local planning authority) came to be geared to normal peace-time activities, action

was taken to prevent unauthorized building, and many existing objectionable and non-conforming temporary structures were demolished. Despite planned endeavours to direct the siting and construction of new, temporary development, demand for accommodation due to increased population and lack of permanent housing caused an increase in temporary building. Measures introduced to enforce control were limited since the local authority was not in a position to offer alternative accommodation or provide suitable sites within the town that could be made available at economic costs. Large areas of valuable town land were, and are today, held in private ownership and, in the absence of adequate legal provision, it was not possible to compel landowners to develop their properties. (Recent legislation has created a Federal Housing Trust and it is hoped that exercise of powers vested in the Trust to designate undeveloped privately held land for compulsory housing development will free these comparatively large sections of the town for this much needed purpose).

Together with unplanned and illegal squatter temporary housing, which in many cases rapidly deteriorated into slums, unauthorized industrial development occurred in residential and commercial quarters. Efforts were made by the Town Board (and subsequently by the newly formed Municipality) to restrict these improperly sited buildings, but shortage of suitable land, lack of supervisory staff, and the primary demands of tin mining to a great extent hindered official attempts to improve the position. All available land known to contain deposits of valuable tin ore was scheduled for prospecting and ultimate working and, by reason of the topography, land required for urban expansion on the northern, eastern, and western fringes of the town was removed from consideration for permanent town building.

In the period 1947–51, plans for approximately 2,000 permanent accommodation units were approved by the local authority, but it is estimated that not more than 1,200 were actually constructed. These represented accommodation for approximately 10,000 persons. On the basis of an equal number of units having been erected in the years 1936–41, permanent housing accommodation for 20,000 persons was provided, whereas the population in 1951 had increased by more than 100,000 individuals. A survey has indicated that approximately 10,000 temporary houses were built within the town limits, providing accommodation for some 85,000 persons. Approximately 6,000 such houses had been built on State land, that is, land that will ultimately be required for Federal and Selangor State Government and Municipal purposes, and these houses must eventually be demolished.

The type of "temporary" house varies from the poorly constructed shanty, costing perhaps a few hundred dollars, to the comparatively sturdy, pre-fabricated structure fitted with modern conveniences, and costing perhaps as much as $15,000 (£1,750 sterling). Co-operative housing societies have been formed since the war to assist in the provision of dwelling units, and many such units have been constructed by these societies; much housing work has also been undertaken by Government for its servants, and by speculative private enterprise.

In order in part to deal with the problem of providing suitable land for overcrowded and squatter housing and for improperly sited industry that had arisen in Kuala Lumpur from the time of the Japanese occupation and which had become intensified by the rapid expansion of the town, a scheme was conceived and designed by the Federal Town Planning Department in 1951 for construction of a new town on a site at Petaling Jaya, some six to seven miles from Kuala Lumpur, and north of the main road and railway to the coast at Klang and Port Swettenham (Fig. 1). This site was selected mainly on account of its adequate areas of reasonably level and undulating land, containing no

economic tin values, being available adjacent to the main road to Port Swettenham, and with convenient road and rail access to the Port and to the parent town of Kuala Lumpur. The scheme was designed to cover an area of 3,000 acres, with a total population of 70,000 persons, based on a number of connected neighbourhood units, with areas set aside for industry, commerce, Government buildings, public recreation, schools, housing and other private and community uses.

Funds for the acquisition of land were made available by the Federal Government, construction was commenced by the State Government in February, 1953 on land which had been cleared of poor quality rubber, and the first roads laid down. The basic unit has been planned around a school and *padang,* with local shopping, housing and open spaces. There are generally 400 houses to a unit, and five such units comprise a neighbourhood. The overall master plan for the complete area of 3,000 acres includes a central market and market stalls, police station, bus station, agricultural station, civic and business centre, Federal Government Offices and, in the industrial area, projects of varying kinds and sizes, having where necessary rail-siding access to the main railway line. It is intended also that a branch track will run from the main railway line to a station situated towards the centre of the town. (Fig. 2).

In the eighteen months during which work has been in progress (since February, 1953) no less than 800 house-units have been completed and occupied, and a further 200 are at present under construction. Twenty shop-houses have been completed and another fifteen are nearing completion. In addition, a Government primary school for 600 pupils has been built, while other buildings constructed and in use include temples, mission houses, a dispensary, a cinema, bus station and market. In the industrial area to the west a large distillery has recently been completed and is in production, in addition to a cannery, a timber-distributing centre, and other light industries giving employment to residents in the new town. To date eighteen miles of road have been laid, some portions of which have been surfaced. Water from a number of wells is piped from a reservoir to the houses in the town reticulation scheme, and it is proposed that eventually the whole town of 70,000 inhabitants will be supplied from the main Kuala Lumpur town supply (which is at present being extended). Soil disposal is by individual cess-pool and emptier.

In the first stage (in the southern area shown in Figure 2) the inhabitants are former residents "directed" from squatter and overcrowded areas in Kuala Lumpur, who have in general built their own homes with partial assistance from Government. Some have had their houses built by local builders under contract. The density of residential development in this first section averages nine houses to the acre. Most of the buildings are of bungalow type, but some are planned as detached units on two floors, and construction is of timber, brick, or concrete. No semi-detached houses or flats have so far been built, but some terraced houses are under construction by the Housing Trust. Land for housing is leased to these tenants on a title for a term of sixty years, carrying a premium of $200 (£23) and a quit rent of $50 (£6) per annum. The cost of houses varies from $3,000 (£350) to $20,000 (£2,300).

In the northern section of the town (to the north of the area shown in Figure 2) it is proposed as a future housing policy to encourage any body or bodies (such as co-operative societies) wishing to build, and the premium and quit rent to be charged for land will vary according to the position of the site and the type of property to be developed. Traversing the centre of the town is a wide strip of worked-out mining land, which it is planned to develop as a public open space, by utilizing the mining pools as attractive scenic centres for boating and, perhaps, swimming in a park-like setting.

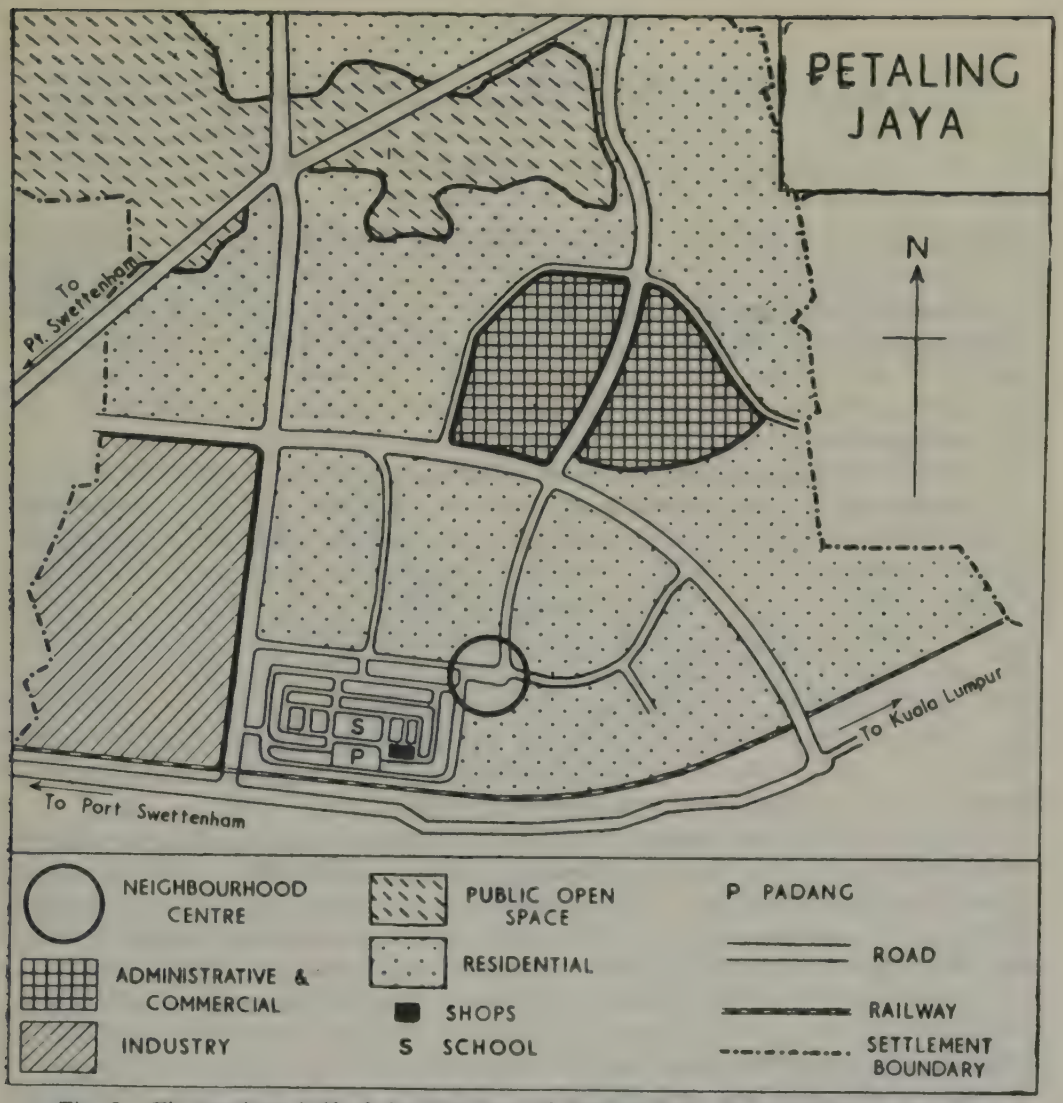


Fig. 2. The southern half of the new town of Petaling Jaya. The public open space is to be developed on exhausted mining land.

Petaling Jaya represents the first example on this scale in the Federation of a complete town planned as a whole by Government, and present indications are that those persons who have already taken up residence are already very contented with their new surroundings and living conditions, a happy augury for the success and future prosperity of this first modern experiment in the establishment of a new town in Malaya.

THE EXPANDING QUEENSLAND SUGAR INDUSTRY[1]

By TIM K. KELLEY, and ALAN D. TWEEDIE

IT WOULD have been difficult for Captain Louis Hope, often referred to as the father of the Queensland sugar industry, to have foreseen the importance of his pioneering efforts in commercial sugar-cane production. Started by his original planting of twenty-three acres near Brisbane in 1863, cultivation has now spread northwards over 500,000 acres along 1,100 miles of this coast. The three per cent of the world's output of cane sugar that is grown here makes Australia the most important commercial producer of the British Commonwealth.

Effects of the sugar industry on Queensland's economic, social and political structure have been far-reaching. With the differences in population pressure in the adjacent continents of Asia and Australia always in view, the close settlement of the coastal belt of more assured rainfall is a matter of extreme significance to the entire Commonwealth. It is claimed that, had it not been for sugar, Queensland's lengthy coastline would have remained largely in primeval forest, with a sparse population based on an extensive beef cattle industry somewhat similar to that of the Northern Territory and North-West Australia. This tropical and subtropical coastal area where the industry is located now supports one-fourth of the State's population and the largest number of working white people in any tropical area, while the majority of its residents are directly or indirectly dependent upon the cultivation and processing of this "brown gold".

About 40,000 workers are employed in cane-field and -mill, and a further 36,000 are estimated to be indirectly employed within the producing districts. Added to those indirectly employed elsewhere, a total of 90,000 workers derive sustenance from sugar growing and manufacturing, so that, including dependents, it may be estimated that one-sixth of the State's entire population relies upon sugar. This is the basis of livelihood for 80 per cent of tropical Australia's 250,000 people, and several tropical communities such as Cairns, Tully, Ingham and Mackay, ranging from 5,000 to 15,000 in population, are largely dependent upon the sugar crop for their existence.

Ranking second only to wool in primary industrial values, sugar exceeds the combined value of all other Queensland agricultural crops. It supplies an indispensable foodstuff to the entire domestic population (Australian *per capita* annual consumption amounts to 154 lb.) and a raw material to such home industries as the manufacture of stock-feeds, syrups, power alcohol, methylated spirits, rum, carbon dioxide gas, building-board, waxes, fertilizers and plastics. Not only is it a major factor in the reciprocal trade between Queensland and the other Australian states, but its importance to the sterling bloc is reflected in the overseas market guarantee of the current British Commonwealth Sugar Agreement. In the vernacular of the Queensland coast, "sugar (here) is a mighty crop".

1. Travel and research for this article was facilitated by a Research Grant from the University of Colorado.

Regional Character

Although in isolated instances the assignment system[1] of controlling production, has tended to subsidise marginal land, the location of the raw-sugar producing areas of Queensland is determined largely by the definite environmental requirements of the cane. Tolerant of a wide variety of soil conditions, the crop requires a minimum annual rainfall of about 40 in. Even more significant is the seasonal distribution of this precipitation for, except under irrigation, the crop will not do well where there is a prolonged and pronounced dry period, the most critical season being the spring and early summer. Ideal climatic conditions both for heavy tonnage of cane and for high sugar-content are those where maximum rainfall and temperatures coincide, where autumn rainfall diminishes sufficiently to prevent the dilution of sugar juices and where winter temperatures are mild.

These climatic requirements and the problems of transport make Queensland sugar a coastal crop (Fig. 1A). Only in isolated instances is production located more than forty miles from the sea, and the greater part of the cane land is no more than fifteen miles from tidewater. Within the eleven hundred miles of tropical and subtropical coast from Mossman to Beenleigh, a wide variety of soil and rainfall conditions gives rise to a discontinuous pattern of production. The southern districts at Bundaberg and Maryborough are separated by two hundred miles of grazing land from the Mackay area, and only the irrigation techniques at Ayr prevent a similar gap between the sugar districts of Proserpine and Ingham. Even in these more favoured areas, a variable climate—wildly erratic in rainfall totals and regimes—results in considerable fluctuation in production from year to year. Cultivation practices and cane-breeding techniques counter these climatic hazards to some extent, but only in the irrigated district of the Burdekin delta can production be gauged with any great accuracy.

Government control of production has resulted in a uniformity in certain cultural practices and manufacturing techniques, but dispersal and varying environments permit the identification of five distinct districts. South from Maryborough, sugar-cane production is restricted to dispersed flood-plain areas, where the crop is part of a mixed agricultural system based on improved pastures and supplementary fodder for dairy herds. In contrast to the monocultural practices of northern areas, sugar-cane plays a minor part in the economic life of the area, the bulk of the assigned holdings being less than twenty acres in extent. Processing is carried on in mills which, with the exception of that at Maryborough, are small, struggling co-operative concerns where high transport costs in the collection of raw material are common, and financial embarrassment an ever-present possibility. The northward migration of the bulk of production, the theme which has characterized the extension of sugar production in Australia, has resulted in the relative and absolute decline of this, the oldest area of commercial production. Today less than five per cent of Australian raw sugar comes from this diverse southern area.

In contrast, the rich volcanic loams and alluvial soils of the Bundaberg-Gin Gin-Childers region support a monocultural cane-growing economy which has shown no diminution through its relatively long history, and which is, with electric reticulation and irrigation, on the threshold of notable expansion. Associated with the sugar industry

1. Sugar for controlled sale by the central authorities is grown on land which is "assigned" to a crushing mill by the central *Cane Prices Board*. Mills can refuse to crush cane grown on other land and in practice such areas are negligible. In consequence, assigned land raises the value of the farm and, despite marginal rates of production in some areas is seldom relinquished voluntarily.

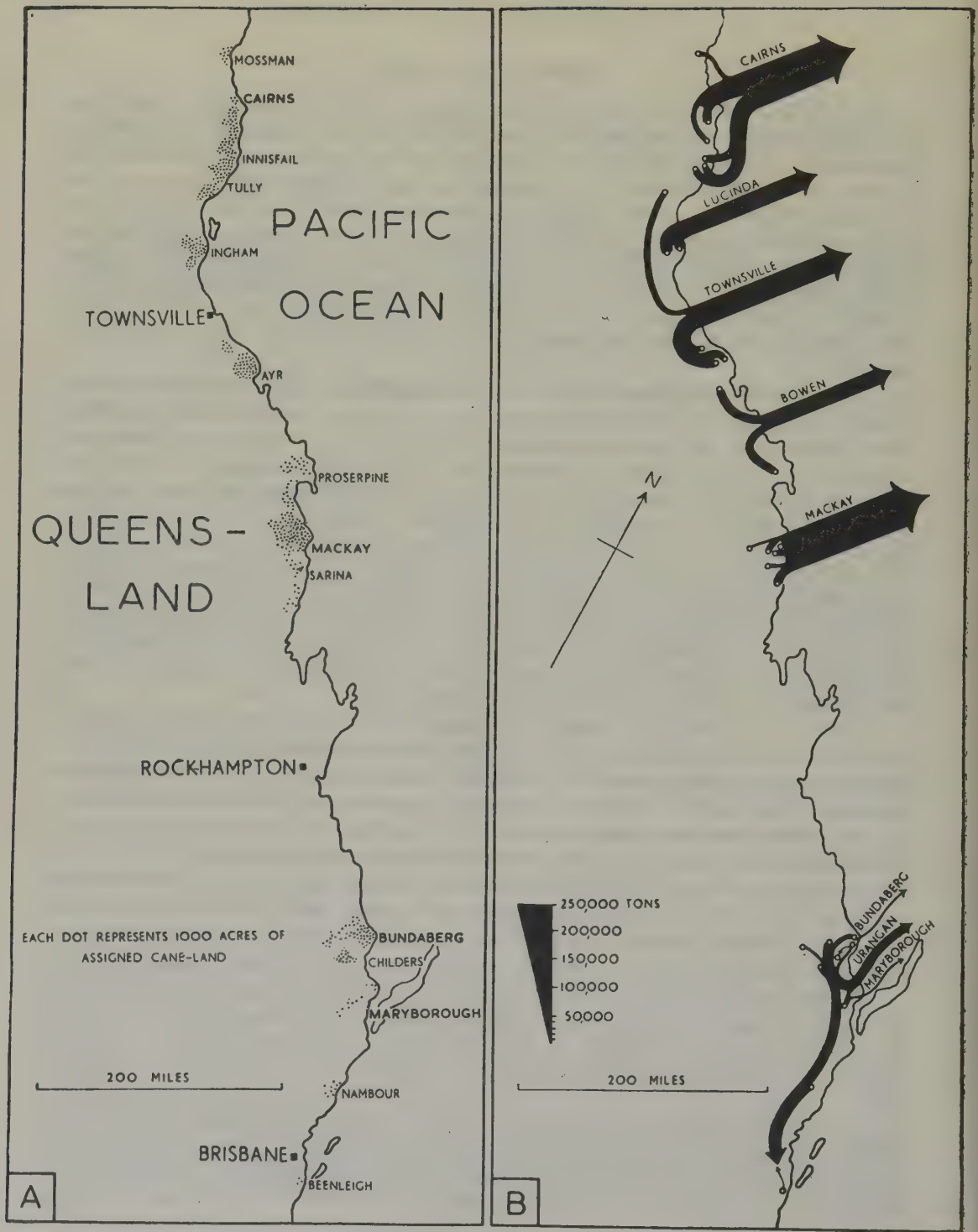


Fig. 1.

A. Sugar-cane production in Queensland, 1953. (Data from the *Australian Sugar Year Book* (Brisbane, 1953).
B. The overseas and interstate movement of raw sugar. (Based on mill peaks, 1953. *See* text p. 53).

from the early eighteen-seventies, it retains today in the Fairymead Estate, practically the sole survivor of the older economy in which the bulk of cane for crushing was grown on the mill plantation. Here, unique in Australia, all phases of manufacture are present, the Millaquin refinery being the sole exception to the general rule that locates the refining processes in the State capitals. Despite the plantation relics, average farms are of the small owner-operated type. Rainfall totals of 40 in. approach the minimum requirements for the crop, but the seasonal regime is such that in a normal year production is possible without recourse to irrigation. Included in plans for the future, irrigation will ensure a more reliable crop and perhaps lessen the dependence of growers on the activities of the cane-breeder whose attentions at the moment are directed to the production of drought-resistant and early-maturing varieties. The southerly location produces occasional frost hazards which are compensated for by the increased hours of sunlight and the more favourable living conditions for white settlers.

In terms of total assigned area, the Mackay-Proserpine region rates high in the list of sugar districts. Soil and climatic problems, however, have lowered yields per acre and recent expansion is a reflection more of the introduction of new hybrid varieties, in particular Q50, than of favourable environmental circumstances. Even with this assistance, shallow soils, lacking in structure and alternating seasonally between excesses and deficiencies in moisture content, have restricted production per acre to the lowest figure for all districts. With one exception, the eight existing mills are co-operative concerns, a unique feature in the Queensland sugar regions and evidence of the fact that it was here that the white-labour experiment was inaugurated. The attractiveness of the industry to migrants of limited capital is illustrated by the success of Maltese immigrants now moving from their poorer original holdings to the richer alluvial silts and contributing more than their share of the district's cane production.

On the alluvial soils of the Burdekin delta, sugar production at Ayr and the adjacent township of Home Hill is founded on readily available supplies of sub-artesian water. Over 80 per cent of the assigned acreage is under channel irrigation from individual pumping units. These methods restrict production to the limited areas of the delta, and even here salt infiltration in the immediate coastal areas prevents the use of some parts for irrigation farming. Controlled but limited production, independent of the vagaries of the 40-in. annual isohyet, is thus characteristic of an area where yields per acre, both of cane and sugar-content, have been consistently higher than those of the other sugar districts of the state. Restrictions of the assignment system have forced Australian growers to use cane varieties high in sucrose content and it is on the Burdekin that this movement has reached its climax. On the average, a ton of sugar is here produced from every six-and-two-thirds tons of cane, or more than four tons of sugar for each acre cultivated.[1] In contrast to the Mackay-Proserpine region, all three mills in the Burdekin delta are proprietary concerns though, as elsewhere, the plantations upon which they were originally based have been all but eliminated. Today only 10 per cent of the cane-lands are held in blocks exceeding 150 acres, and the co-operative activities of Italian immigrants have, despite higher prices for irrigated land, resulted in their controlling almost half of the assigned area.

The discontinuous areas between Ingham and Mossman are at once the youngest and, in terms of raw sugar production, the most important of the cane-growing regions of Queensland. High temperatures and a plentiful summer rainfall are conducive to heavy crops but the rainfall, if prolonged, tends to reduce the sucrose content of the

1. *Australian Sugar Year Book* (Brisbane, 1953), p. 75.

crop, as well as being a deterrent to early and continuous harvesting operations. Large crushing mills fed by small, owner-operated holdings are typical of a district that has in large part been won from the encircling rain-forest since the establishment of complete governmental control of the industry. The assisted migration of south Europeans in this period is reflected in the high proportion of farmers of Italian descent, a proportion averaging 50 per cent for the area as a whole but reaching as high as 75 per cent in the Ingham district. Despite this, however, sugar production here almost doubles that from an equal area in the Mackay-Proserpine region, and rates second only to the controlled production of the Burdekin delta in returns per acre. In the main, it is for this area that an expanding industry looks for greater production.[1] To some degree a reflection of the environmental conditions, this outlook has also a social and political background. The association with close settlement of the tropics, which has always been a feature of the sugar industry, is stronger here than in the south where, it is suggested, an alternative land-use system might achieve the same demographic result.

Cultivation

Three main factors determine the yield of sugar: the area harvested, the seasonal conditions and the efficiency with which cane is grown and milled. With the exception of the period of the last war, rapid expansion has been a feature of the industry, and the area harvested annually has increased from 75,000 acres at the turn of the century to a present 275,000 acres, the most rapid development occurring in the nineteen-twenties. Although Queensland's eastern seaboard has a more reliable rainfall than the interior, seasonal fluctuations adversely affect sugar yields and irrigation, notably in the Lower Burdekin area, is becoming increasingly important in an attempt to overcome this environmental handicap. Technical progress in both field and mill has been characteristic until today Queensland exhibits a high level of productive efficiency. Early yields of 1·5 tons of raw sugar per acre, when 10 tons of cane were required for each ton of sugar produced, have been steadily improved (Fig. 2). Today, due to the breeding of more robust, higher fibre-content canes, it requires an average of 7·3 tons of cane to provide one ton of sugar, but improved methods, new cane varieties and disease and insect control have more than doubled the yield of sugar per acre, and placed Queensland second only to the irrigated production of Hawaii.

In conformity with the practices of other cane-growing countries, production was originally based on plantation units, the field work being done by Kanakas indentured from the South Sea Islands. By 1900 the industry had become sufficiently important for Queensland to stipulate, as a condition of her entry into Federation and acceptance of the White Australia policy in 1901, that a profitable home market should be guaranteed. Further indentured labour was prohibited and most of the islanders repatriated by 1906. Today only three of the former plantations remain and the present industry is essentially one of small growers, with each of the 8,000 farmers cultivating an average of 50 acres of cane. Less than four per cent of the total assigned area is in holdings exceeding 250 acres.

By far the greater part of the cane-lands have been developed from dense, tropical rain-forest or from the more open eucalypt associations, the latter usually reflecting less favourable climatic and edaphic conditions. Clearing costs are high. Though conditions

1. *Report of the Royal Commission to prepare the Orderly Plan for the development of the Sugar Industry*, (Brisbane, 1951).

vary from district to district and from soil to soil, the preparation of previously uncultivated fields usually involves three ploughings, one grubbing, one rolling and one harrowing. Planting in the north is done mostly during the autumn months following the "wet"; in southern and central districts, it is usually practised during spring and summer months. The cuttings, planted at 18-in. intervals in rows from four to five feet apart, are set and fertilized in one operation by mechanical planters.

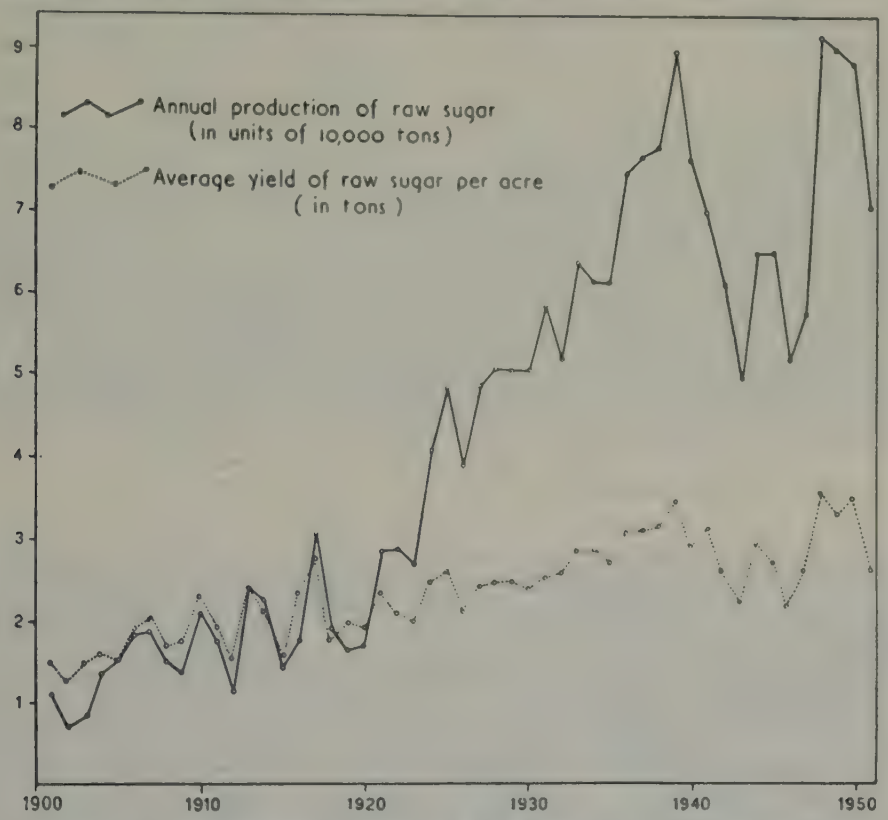


Fig. 2. Queensland sugar production and yields, 1901–51. The graphs illustrate the close parellelism between trends of total production and yield per acre. Their divergence during the period 1920–5 was the result of a rapid and largely uncontrolled extension of cane-land in those years.

(Data from the *Australian Sugar Year Book* (Brisbane, 1953).

Under suitable conditions the buds germinate and show above the surface within two or three weeks, after which, by frequent and careful surface cultivation, weeds are controlled and soils are kept friable and levelled for subsequent harvesting. With the exception of some weeding practices, all operations are entirely mechanical. When the crop is nearly "out-of-hand", a top-dressing of sulphate of ammonia is applied. By this time foliage shades the interspaces completely, weed growth is checked, and further cultivation is suspended. With the exception of irrigated farms, crop results then rest with the weather conditions. For much of Queensland, spring rainfalls are all-important in determining the size of the harvest.

The dependence of the cane-grower on relatively high-cost white labour engendered the development of labour-saving devices, many of which were for years peculiar to

Queensland. At the present time, every operation up to the point when the crop stands ready for harvest is mechanized. If the boom-sprays now being pioneered are successful, the chipping of weeds in cane rows, at present the only manual labour in cane cultivation, will be eliminated. Such advances to reduce labour costs have naturally resulted in the necessity for each farm to possess a comprehensive array of farm machinery, an unavoidable overhead in the small-farm economy, and another item in the overall expense involved in the maintenance of a White Australia policy.

Harvesting

All varieties of cane show a marked variation in sugar-content throughout the year, and it is this factor which limits the harvesting of the cane and the manufacture of raw sugar to a particular season each year. Though cane matures earlier in the north, by and large it can be said that the overall sugar content (measured as per cent commercial cane sugar, or C.C.S.) is at its peak in late September and early October, falling away noticeably in the rainier conditions of December. Consequently, the harvesting period with its heavy labour demands, occurs between mid-May and December. In parts of south Queensland, as in the small Northern Rivers district of New South Wales, harvesting operations are delayed by a two-year growth cycle. North of Bundaberg, however, cane is cut in the season following that in which it was planted or, in the case of ratoon growth, that in which it was cut.

Cane is harvested by cutting at ground level with a large knife. The green top is trimmed and the stalk loaded on to trucks, the whole operation being manually performed. This, though the most arduous of all farm work, has in the past, been sufficiently rewarded to attract adequate labour—New Australians and residents of the South alike—to make up the necessary force which rises from some 2,000 workers at the beginning of the season to 8,000 at the height of the harvest. In the past many such cutters have eventually become growers, for the industry has tended to be more attractive to the settler with limited capital than other primary industries in the Commonwealth. Through co-operative efforts and by such methods, Southern European immigrants now hold some 25 per cent of Queensland's sugar assignments. Cutting in the Northern District is usually done by gangs of from six to ten men directed by the mill concerned and rotating from farm to farm when cane is ready to be cut. To the south, smaller gangs tend to remain on one farm for the entire season, assisted frequently by the farmer-owner. Payment is made on contract rates per ton, the average worker cutting and loading some 25 to 30 tons in a rigidly controlled forty-hour working week.[1] As a result of war-time labour shortages and subsequent labour demands, burning of cane before harvesting has become a standard cultural practice. Provided that milling is accomplished within forty-eight hours, the practice does not significantly injure the cane, while harvesting is speedier and cheaper, but a large amount of organic matter is lost to the soil to the detriment of soil structure, if not to soil fertility.

Attempts to introduce harvesting machines have been largely unsuccessful and difficult to adjust to the Australian industry of small farms. Despite the limited success of experiments on the Fairymead plantation at Bundaberg, the inability of loading machines to keep pace with mechanical cutters has meant that the experiment has had restricted application.

1. Although few men stay at this work after reaching their fortieth birthday, the cutting rates of Queensland's white labour force are significantly higher than rates obtainable elsewhere by manual methods, and are a strong argument in support of theories of white occupance of the tropics.

PLATE III

Cane-fields near South Johnstone, a few miles south of Cairns.

A cutter-planter. The eucalypt bush in the background indicates the difficulties encountered in clearing new assignments.

(Photographs by courtesy of the *Queensland Department of Agriculture and Stock*).

Hoisting cane from horse to rail, near Proserpine.

Tipping cane into the mill near Ayr. The cane is then removed by a conveyer-belt to the rollers, where it is crushed to extract the juice.

(Photographs by courtesy of the *Queensland Department of Agriculture and Stock*).

In general two ratoons are grown, the 10-per-cent reduction in ratoon production being offset by lower costs. Indeed, legislation by which no grower with gross assignments in excess of fifteen acres may harvest more than 75 per cent of his assigned area in any one year, is intended to standardize the rotation of two ratoon crops and a green manure crop. In the event of the green manure crop being absent, owing to limited seed supplies or adverse climatic conditions, plant nutrients are restored by liberal dressings of sulphate of ammonia. In areas where water supplies are a problem, ratooning is not favoured as the "tilling up" of the stubble makes it difficult for the plant to secure sufficient moisture.

Transport

In weight of crop handled after harvesting, cane exceeds even the entire Australian wheat crop. Accordingly transport to the mills, in the main by land haulage, is a heavy task. Truck haulage accounts for 5 per cent of the total crop, and government railways carry 15 per cent. The remaining 80 per cent is hauled by the mill companies over the 1,500 miles of permanent tram-lines established for the purpose. The network is extended in the higher-rainfall areas of the north by some 500 miles of portable lines, laid as required into the fields. In the drier south trucks are more important as feeders in the haulage system.

Seasonal demands on the transport system are consequently very heavy, heavier possibly than need be. In some areas, harvested cane is carried past one mill to be treated in another, an anomaly that only the existing system of mill assignments and the economics of the co-operative system can explain.[1]

A further strain is placed on the existing transport system by the movement of raw sugar overseas and between states later in the season (Fig. 1B). Inadequate port facilities mean expensive lighterage or long rail haulage. The channelling of the bulk of the crop through Cairns, Lucinda, Townsville, Bowen and Mackay places seasonal stress on the storage and handling capacities of these ports.

Milling

Primitive milling equipment and difficulties of transport combined to make the small plantation mill the practical unit of the pioneer days of the industry. As plantations were subdivided following the exclusion of Kanaka labour, so the mills increased in size and efficiency. Today thirty-two mills crush a million tons of cane annually; in the 1888 season, 360 plants crushed only 59,000 tons.

By reason of their isolation from large industrial and commercial centres, sugar mills are self-contained units located in the midst of the fields that supply the cane. Representing a present-day replacement value of £A3,500,000 and the organizational and operational centre of the whole industry, the crushing mill is today a highly specialized modern factory. Allocations of quotas, arrangements for hauling, distributions of cane plants, disease and insect control, and the distribution of fertilizers are often closely associated with the mill. Fourteen of the thirty-two Queensland mills are co-operatively owned and managed by the growers themselves.

1. Recent attempts in the Mackay area to eliminate these anomalies met with stiff resistance from growers who preferred the longer haul to a larger and more prosperous co-operative mill.

By-products

Three main by-products arise from the manufacture of raw sugar, viz.: bagasse, the cane fibre from which the juice has been extracted; mud, removed in the clarification of the juice; and molasses, which remains after the sugar crystals have been separated from the mother liquid. The valuable properties of all these are used to advantage. There is little wastage at the modern mill.

Bagasse, the moist, woody fibre possessing one-fourth the calorific value of coal is capable of meeting the steam needs of the sugar-mill when fired in specially designed furnaces. Automatic conveyers from crushing rollers to furnaces carry enough of the annual production of 1,500,000 tons to supply 85 per cent of the fuel requirements of the industry, which would otherwise need 375,000 tons of coal during the normal season's run. A small amount of bagasse is used in the manufacture of "cane-ite", a fibre building-board, and the possibility of the use of the remainder in the production of paper pulp is under review.

Filter-press mud, a by-product containing soil, fine bagasse particles, moisture, plant foods, and the wax which coats the cane, has good fertilizer value and is returned to the cane-field. Pilot plants now in operation are attempting to recover waxes on a commercial scale. Produced at the average rate of four gallons per ton of cane, molasses, which contains potash and nitrogen, is a useful fertilizer. Its application is also beneficial to soil structure. About one-quarter of the season's total production of molasses is applied to cane-fields, and a similar amount is used as a high energy-producing stock-feed, especially popular during times of drought. The remainder is distilled for such products as rum, alcohol, spirits and gases.

Marketing

Because the industry has been a means of populating the tropical coast, and in its beginnings was uneconomic, it is characterized by a high degree of organization and regulation. Much of this is due to the fact that the industry is concerned with both primary and secondary production. It deals with a very bulky crop which, because it must be treated at a steady rate in the shortest possible time, requires highly organized transport facilities. Yet within this regulatory framework, private enterprise in the form of owner-growers, mill owners, co-operative mills, and refining companies, operates a successful large-scale business.

For many years after Federation, Australia did not produce enough sugar to satisfy its own requirements. During the first World War considerable quantities were imported; and as late as 1923 the Commonwealth was still an importer of some 100,000 tons annually. Since that year, however, it has been independent of outside sources. In 1915, owing to the effects of the War, partial failure of the crop, and the high costs of imported sugar, the State and Commonwealth governments agreed to take control of all marketing. Under this agreement the Queensland government acquired all sugar produced in both that State and in New South Wales and arranged for its refining and sale,[1] the Commonwealth guaranteeing purchase at a fixed price. In 1923 the period of direct Commonwealth control ended; financial and marketing controls were handed over to the Queensland government.

1. New South Wales produces about 5 per cent of the total output.

Regulation of production and prices has since been complete and stability of the industry ensured. Wages and industrial conditions are governed throughout the industry, offering justification for the claim that it is the most intensively organized agricultural industry in the Commonwealth. The amount of cane that can be produced per farm (farm peaks), the mill to which it may be delivered (assigned land), the quantity of raw sugar that each mill may produce (mill peaks), the price the mill pays the grower, the price the refiners pay the mill, the wages paid to cutters and the hours which they may work, and the price at which the refiners may sell to wholesalers are regulated. At each stage controls are exercised by bodies in which the interests of all parties are represented.

Unfortunately Australia became a sugar exporter at a time when there was a surplus of world sugar production and the world price was only £8 a ton compared with the Australian home price of £24. This situation was met by a pooling of returns from both domestic and overseas sales and payment of an equalized price to producers. To assist Empire sugar producers, the United Kingdom and Canada granted a preferential tariff on Empire sugar which helped in the disposal of Australia's surplus. Problems of over-production and low returns were so acute for the sugar industry throughout the world by 1937, that producers accepted a restriction policy, the International Sugar Agreement, under which Australia received an export quota of 400,000 tons. During the war years Agreement quotas lapsed.

Since World War II the outlook for Queensland's sugar industry has changed drastically. The disposal of surpluses at a loss is no longer the problem. Now it is a battle of production in an effort to provide a crop sufficient to cover Australia's increasing requirements and to meet Empire demands.

Present Expansion

Post-war developments within both the British and Australian Commonwealths have sponsored a programme of expansion in Queensland sugar production. Designed at the time of Australian Federation in 1901 to supply the needs of a limited local population, and modified in 1924 to compete in protected British markets, the sugar industry has, since 1930, met increased commitments by the intensification of production on a declining acreage. A vigorous post-war immigration policy and sugar shortages in the sterling area, however, make demands that can no longer be fully met in this fashion. In 1949, for the first time since 1930 (with the limited exception of provision for the settlement of ex-servicemen in 1946), the controlling body authorized a substantial increase in the acreage assigned to cane, and the steady decline in this area which has characterized the past two decades has been reversed by an increase of 40 per cent.

Unlike the rapid expansion of the industry in the early nineteen-twenties, when Australian sugar attempted to exploit the sugar-exhausted markets of a war-torn Europe, the current programme is rigidly controlled. Australian sugar production has been controlled by legislation since 1925 when a Central Board was established to licence cane-land through the system of mill peaks and assigned lands. Authorized to review the situation periodically in terms both of production and markets, the Board can, if a "change of circumstance" is deemed to exist, recommend to the government that changes be made either in the amount of sugar to be milled or in the acreage of land assigned for sugar production.

The decision to boost Australian population by the assisted migration annually of 150,000 "New Australians" from Europe and the British Commonwealth Sugar Agreement of 1949 constituted the "change of circumstance" required. By this agreement, the

Australian export quota of 400,000 tons in the 1937 International Agreement has been increased to 600,000 tons, half of which is to be purchased by the United Kingdom at prices to be negotiated annually, the remainder to be marketed at world prices, plus Empire preference, in either the United Kingdom or Canada.[1] It was to meet this 200,000-ton increase that the Central Board first recommended increased assignments.

Future home-market requirements are less precisely defined but will undoubtedly be much larger than at present. The question was fully reviewed in 1950, when an estimated population increase, resulting both from immigration and natural increase, for the period 1950–75 was given as five millions.[2] On the basis of the contemporary *per capita* consumption, this represented a 1975 home-market demand of 759,000 tons, an increase of 50 per cent over the present figure. Subsequent investigation suggests that the basic *per capita* consumption included "masked" sugar exports—as heavy syrups, etc.—to a rationed Britain, a trade which, unprotected by tariff, existed only as long as Australian prices were below the world figure. Internal conditions, moreover, have at least temporarily slowed down the rate of immigration. In the light of these later disclosures, the Central Board has accepted only in part the recommendations of the Royal Commission. Even so, the expansion programme to be completed in the 1953/4 season is considerable. It aims at a total production of 1,162,600 tons of raw sugar, an increase of 300,000 tons in excess of the 1949 mill peaks.

The objective is to be attained both by an increased allotment to existing farmers, in particular to those with assignments considered smaller than that "required for an economic living", and by the establishment of new farms. By reason of the historical development of the industry, the greater number of these small holdings is found in the areas south of Proserpine, and in consequence 70 per cent of the sugar increase to be obtained from existing producers will come from the three southern regions. The other half of the proposed total increase will come from some 830 new farms which, together with 252 ex-servicemen already established, represents an increase of 1,082 new farmers in tropical Australia.

In keeping with a policy aimed at the maintenance of the existing rate of production in the five sugar districts, most of the new assignments are allotted to the Northern and Burdekin districts, where new land is readily available. The expansion of cane production here, however, means that the already large mills will be stretched to the limits of their existing milling trains. The new hundred-settler block of the Abergowrie area, near Ingham, has been met by the duplication of the Victoria Mill, but the 1950 investigation suggests that such a process would not be favoured by co-operative mills already committed to existing growers and unwilling to face the heavy expenditure involved in duplication. The alternative, namely, the creation of new mills, would be even more expensive and is considered uneconomic at the present time. Admittedly half the ten mills of the Northern Region are proprietary mills and might consider following the Victoria example, though this would be possible only if suitable land for expansion existed in the mill area. These reasons suggest that the present expansion might well be the last to maintain the existing ratio of district production. For economic reasons further expansion might be forced to look to the less extended mills of the areas south of

1. *Report of the Royal Commission to prepare an Orderly Plan for the Development of the Sugar Industry* (Brisbane, 1951).

2. The 1953 World Conference, held in the United Kingdom, reached a decision which allows Australia the same overseas market as the Empire Agreement, thus strengthening present expansion tendencies.

Mackay, thus reversing the northward trend that has characterized the industry since its beginning. The possibility of mill migration, however, is not without precedent, and should not be overlooked.[1]

The 1949–54 expansion scheme, therefore, will effectively alter the acreage structure of the three southern districts and, by effecting a more stable, secure and closer settlement, will be achieved with little strain on existing transport systems. The demands of a larger crop in the north can be met by an extension of the existing systems which, as illustrated by the Tully-El Arish scheme, can be economically installed by individual mills. A straining of existing transport facilities, in particular port-loading, for the processed sugar does, however, represent a weak link in the chain of sugar expansion. Low loading rates and labour strikes have, in the 1952/3 season, created serious bottlenecks in the North Queensland ports, with a pile-up in November 1952 of one-quarter of a million tons. Expansion allows for an increase in 1953/4 of at least 200,000 tons more than in 1952/3. At the present rate of removal this could mean that nearly half a million tons of sugar would be in store at the season's end, with little possibility of its being cleared before the beginning of the next crushing season. A solution to the problem is being sought in bulk handling techniques at the nine Queensland sugar ports. This will also mean the installation of unloading equipment at the refinery wharves of the state capitals, as well as in the United Kingdom, Canada, and New Zealand. Much of the cost will be recovered by the saving on jute for bagging, which at the moment is costing the industry £A2 million per annum. Further relief may be afforded by the provision at Mourilyan harbour of conditions satisfactory to overseas and interstate shipping. This would eliminate double handling and relieve the seasonal pressure at Cairns.

Better port facilities are important, too, in the maintenance of overseas markets, upon which the present expansion scheme is based. The sugar industry and the associated development and settlement of northern coastal Queensland has, since the nineteen-twenties, been intimately connected with the tariff preferences in the United Kingdom and Canada. The present agreement guarantees a market price for only half the projected export. The remainder, destined in large part for the Canadian market, has no place in the negotiated price system. Its export is based solely on the operation of tariff preference, and the existence of the trade depends on an ability to compete in both price and quality on the world market. Increasing production in other areas, as yet uncontrolled by international agreement, may seriously affect the price situation, for Canada is free to buy in both dollar and sterling areas.

Important, too, is the quality of the sugar. The ice-bound condition of eastern Canadian ports in winter prevents the import of Australian sugar during the southern crushing season, and in consequence raw sugar for the Canadian market is taken from store in the autumn months. Speedier loading facilities at Queensland ports would do much to minimize the risk of sugar deterioration and its possible non-acceptance by Canadian refineries. The installation of bulk-handling machinery has already been approved for the ports of Mackay and Lucinda, and the situation at Cairns is under review. The problems of both transport and the Canadian market, key points in the expansion programme, can best be solved by modern loading methods which free the sugar industry from the industrial disputes which have long been characteristic of the Australian waterfront.

1. As, for example, the transfer of the Invicta Mill from Bundaberg to Giru, near Townsville, in 1919.

Solution of the problems of transport and the quality of sugar for the Canadian market, however, by no means guarantees the complete success of the Queensland sugar expansion scheme. There appears to be little doubt that the State has the ability to produce, process and transport all the raw sugar required for home and overseas commitments. There seems to be less reason for optimism with regard to Queensland's ability to produce such an increase at a price satisfactory to consumers both in Australia and abroad. In the past, high and increasing labour costs have been met by increased efficiency, both in field and mill. Since 1950, however, significant rises in the net price of raw sugar both for home consumption and for export suggest that the ability of the industry to absorb these costs may be approaching saturation point.[1] These appears to be little likelihood of a reduction of such costs in the foreseeable future. Admittedly, the irresponsible tactics of the industry's skilled workers at the beginning of the present crushing season,[2] will cause little total increase, while, although the recent arbitration court decision of an overall 5-per-cent wage increase to sugar workers might be absorbed in an expanding industry, the new increase of 15 per cent in the cutting costs of burnt cane will greatly increase production costs.

Presumably increased prices for home-market sugars can be adequately protected by tariff, though the possibility of increased consumer-resistance should not be discounted. Related industries such as jam- and fruit-canning, the products of which are marketed abroad, might find difficulty in facing the increased cost of raw materials. Already such industries have expressed concern at their inability to compete in world markets. Sugar price increases might well cripple the juvenile pineapple-canning industry of Queensland.

Only a limited control, moreover, can be maintained over the export market. Although the Commonwealth Sugar Agreement allows for eight years' notice of withdrawal by either party, the controlled production of Queensland might be reduced necessarily to meet the changed circumstances, for at least half the present export can be marketed in the United Kingdom or Canada only so long as the export price, less tax preference, is below world prices. While it must be admitted that the Queensland sugar industry is not alone in facing the problems of increased production costs, it may also be doubted whether the United Kingdom or Canada would be prepared to raise tax preferences to subsidize an Australian attempt at expanded white settlement in the tropics.

1. *Australian Sugar Year Book*, p. 51. Average prices for 1952 are almost 50 per cent higher than those of 1950, in sympathy with a similar increase in basic wages in the same period.
2. Mill engineering staffs struck for increased marginal rates over the basic wage and delayed crushing of an anticipated record harvest.

AN EARLY CHINESE REFERENCE TO PART OF MALAYA

By PAUL WHEATLEY

IN THE *Liang Shu* (梁書), a Chinese dynastic history compiled in the first half of the seventh century A.D., there is recorded an itinerary from the Hinduized kingdom of *Fu-nan*, situated astride the Lower Mekong River, to India.[1]

> 吳時扶南王范旃遣親人蘇物使其國從扶南發投拘利口
> 循海大灣中正西北入歷灣邊數國可一年餘到天竺江口

. . . in the time of the Wu [dynasty], the king of *Fu-nan* . . . sent one of his relations, Su-wu, on an embassy to this kingdom [India]. From *Fu-nan*, going to the port of *Chü-li*, he [then] followed the sea into a large bay. Directly to the north-west he entered and passed through the bay, on the shores of which were several kingdoms. In rather more than a year he reached the mouth of the *River of India*.[2]

In a gloss in the *Shui ching chu* (水經注), which dates from the beginning of the sixth century, we find another version of the same route, quoted from K'ang T'ai's memoirs.[3]

> 發拘利口入大灣中正西北入可一年餘得天竺江口名恆水江口

On leaving the port of *Chü-li*, one enters a large bay. Going directly north-westwards, in rather more than a year one reaches the mouth of the *River of India*, that is, the mouth of the *Heng-shui River*.

The kingdom of *Chü-li*, which features as the starting point for both itineraries, is mentioned again in the *Sui Shu* (隋書), quoted by the *T'ai p'ing yü lan* (太平御覽),[4] an enormous compendium compiled between A.D. 977 and 983 for the first emperor of the Sung Dynasty.

> 隋書曰 . . . 拘利國(一作九雅) . . . 扶南度金隣大
> 灣南行三千里有此國其農作與金隣同其人多白色

The *Sui shu* states that . . . the kingdom of *Chü-li* (also called *Chiu-ya*) . . . is situated across the *Great Bay of Chin-lin* [Gulf of Siam] from *Fu-nan*, and 3000 *li* southwards. Its agriculture is the same as that of *Chin-lin* [a country situated on the northern shore of the Gulf of Siam]. Among the inhabitants are many with white complexions.

1. Chap. 54, f.22, verso (百衲本二十四史 Edition).

2. It has sometimes been thought that the characters 投拘利 should be read as a place-name, *T'ou-chü-li*, but I have elsewhere given reasons why this interpretation can no longer be accepted—"Belated Comments on Sir Roland Braddell's Study of Ancient Times", *Journal of the Malayan Branch of the Royal Asiatic Society*, vol. 28 pt. 1 (Singapore, 1955).

3. Chap. 1, f.12, verso (四部備要 Edition). K'ang T'ai was a member of an embassy from the Court of China to *Fu-nan* in c. A.D. 245. His memoris are the main written source for our knowledge of the early settlements on the Malay Peninsula—see P. Wheatley, "The Malay Peninsula as known to the Chinese of the Third Century A.D.", *JMBRAS*, vol. 28, pt. 1 (1955).

4. Chap. 788, f.6, recto et verso (宋板 Edition).

These latter pieces of information are also recorded in parallel passages in the *T'ung tien* (通典), an eighth century encyclopedia,[1] and in a compendium of the Sung Dynasty, the *T'ai p'ing huan yü chi* (太平寰宇記),[2] published c.A.D. 980, but *Chü-li* there appears as *Chiu-li* (九離). Clearly 拘利 and 九離 are attempts by different authors to represent the same sounds, while the alternative 九雅 has crept in as a scribal error, the characters 離 and 雅 bearing some degree of resemblance to each other. Anyone familiar with a text which has been copied repeatedly will realize the virtual impossibility of avoiding occasional errors of this nature.

Moreover, it seems that this is not the only discrepancy which has become incorporated in the Chinese histories. In the *Liang Shu,* for example, we read the following passage.[3]

復以兵威攻伐旁國咸復屬之自號扶南大王乃治作大船窮漲
海攻屈都昆九稚典孫等十餘國開地五六千里次當伐金隣

> Once more he [Fan-man] used troops to attack and subdue the neighbouring kingdoms, which all acknowledged themselves his vassals. He himself adopted the style of *Great King of Fu-nan.* Then he ordered the construction of great ships and, crossing right over the *Chang-hai* [South China Sea],[4] attacked more than ten kingdoms, including *Ch'ü-tu-k'un, Chiu-chih* and *Tien-sun.*

Tien-sun, I have shown elsewhere,[5] was situated on the Malay Peninsula. As Fan-man had to "cross right over the South China Sea" from *Fu-nan* to reach *Chiu-chih,* then it is more than probable that that country, too, was on the Peninsula, a supposition corroborated by evidence discussed below. But the *Chü-li* mentioned above, which lay to the south-east of India, must also have occupied a part of the Peninsula; and there seems a strong possibility that *Chiu-chih* (九稚) and *Chü-li* (拘利) are the same place. Once again we seem to have an instance of careless copying, 利 now appearing as 稚. But even this is not the end of the story, for it seems that this same kingdom is also mentioned, under the orthography *Chü-chih* (句稚), in a quotation from the *Nan chou i wu chih* (南州異物志), preserved in the *T'ai p'ing yü lan.*[6]

句稚國
南州異物志曰句稚去與遊八百里有江口西
南向東北行極大崎頭出漲海中淺而多磁石

> The *Nan chou i wu chih* states that *Chü-chih* is 800 *li* from *Yü-yu.* There is an estuary running from south-west to north-east and a very large headland jutting out into the *Chang-hai* [South China Sea]. The water is shallow and full of loadstones.

On the same folio there is a further quotation from the same source.

南州異物志曰歌營在句稚南可一月行

> The *Nan chou i wu chih* states that *Ko-ying* is about one month's journey south of *Chü-chih.*

1. Chap. 188.
2. Chap. 177.
3. Chap. 54, f.9, recto.
4. See *K'ang hsi tzu tien* (康熙字典) under 漲 and *P'ei wen yün fu* (佩文韻府), chap. 40, under 海.
5. Wheatley, op. cit.
6. Chap. 790 f.7, verso.

Finally, the sixth-century *Lo yang chia lan chi* (洛陽伽藍記) says of the travels of the monk Bodhibhadra:[1]

北行一月日至勾稚國北行十一日至孫
典國從孫典國北行三十日至扶南國

> . . . after journeying northwards for one month [from *Ko-ying*][2] I reached the kingdom of *Kou-chih*. After travelling northwards for eleven days I arrived at the kingdom of *Sun-tien*.[3] From *Sun-tien* I went northwards for thirty days, when I came to the kingdom of *Fu-nan*.

Over the last half-century there has grown up an ill-defined notion that the *Chü-li*[4] of the Chinese records may have been the same place as the *Kole* which features in the Ptolemaic *Geography*. The exact site of this port is still a matter of debate. Gerini placed it in modern Kelantan,[5] Berthelot hesitantly suggested Tanjong Penunjok[6] while Braddell thought *Kole* might be on the Kemaman estuary.[7] Clearly Ptolemy intended to depict a town on the north-east coast of the Peninsula. Now the fact that *Chü-li* was situated south-east of the Ganges delta, and more than a year's sailing from that point, implies that it was either on the Malay Peninsula or in the Archipelago. But, relative to *Fu-nan,* it was also "across the Gulf of Siam" (*Sui shu*) and "right over the South China Sea" (*Liang shu*), and the only position able to meet both these spatial requirements is a point on the north-east coast of the Malay Peninsula, that is, in the locality of the Ptolemaic *Kole*. There can, in fact, be little doubt but that *Kole* and *Chü-li* are the same place. The length of time it took to sail from the north-east coast of Malaya to the Ganges would take into account the period of waiting for the change of the monsoon before vessels could round the Peninsula.

Can we now locate *Kole* or *Chü-li* more precisely? Summarizing the evidence discussed above we find that

Kole — *Chü-li* (拘利)
— *Chiu-li* (九離)
— *Chiu-ya* (九雅)
— *Chiu-chih* (九稚)
— *Chü-chih* (句稚)
— *Kou-chih* (勾稚).

Now, from the *Nan chou i wu chih* we also know that the kingdom of *Chü-chih* included an estuary running from south-west to north-east and a headland protruding into a shallow reach of the South China Sea, while it was also some forty days' sailing south of *Fu-nan*. The compass bearings in these early passages are doubtless no more than general directions, yet it is clear that the combined testimony of the *Lo yang chia lan chi* and the *Nan chou i wu chih* corroborate that of Ptolemy, the *Liang Shu* and the

1. Chap. 4, f.18, recto (四部叢刊 Edition).

2. *Ko-ying* cannot be identified, but the *Lo yang chia lan cih* (Chap. 4, f.17, verso) makes it clear that it was in the South Seas: 南中有歌營國去京師甚遠風土隔絕世不與中國交通雖二漢及魏亦未會至也. See also P. Pelliot, "Textes chinois concernant l'Indochine hindouisée", *Etudes Asiatiques*, vol. 2 (Paris, 1925), pp. 249-51.

3. For the identification of this place-name see Wheatley, op. cit.

4. Pronounced *Kiu-li*. See B. Karlgren, *Analytical Dictionary of Chinese and Sino-Japanese* (Paris, 1923).

5. G.E. Gerini, *Researches on Ptolemy's Geography of Eastern Asia* (London, 1909), pp. 105-6.

6. A. Berthelot, *L'Asie Ancienne Centrale et Sud-Orientale d'après Ptolémée* (Paris, 1930), p. 387.

7. Sir Roland Braddell, "An Introduction to the Study of Ancient Times in the Malay Peninsula and the Straits of Malacca", *JMBRAS*, vol. 14, pt. 3 (1936), p. 37 and vol. 17, pt. 1 (1939), pp. 203 and 206.

Shui ching chu. One location pre-eminently recommends itself as conforming with these geographical exigencies, namely, the estuary of the Kuantan River. Many of the east-coast rivers, it is true, flow in a general north-easterly direction, but nearly always their mouths are diverted by bars and spits. The Trengganu River, which is otherwise suitable, has no prominent headland in the near vicinity.

Confirmatory evidence for the location of *Chü-li* (= *Kole*) in this position can be deduced from the *Geography* itself. We know that the author of that work had no astronomical observations from the region of the equator, so that he was forced to calculate its position relative to the northern tropic; but as his degree was only five-sixths of a true degree, he misplaced his equator about 230 nautical miles too far to the north. However, the Ptolemaic map was based on times and distances and not on latitudes and longitudes, so that *Kole,* placed just north of the equator, would in fact be some 230 nautical miles further north; and it is at approximately this distance from the true equator that we find the Kuantan estuary.

PHOSPHATE DEPOSITS OF BRITISH BORNEO[1]

By G. E. WILFORD

The Niah Caves, Sarawak

Guano deposits and rock phospate estimated to amount to 28,700 tons occur in the Niah Caves at Gunong Subis in the Fourth Division of Sarawak. The caves, which are situated about six miles south-west of the village of Niah and forty miles south-south-west of Miri (Fig. 1), have been important for over a century, mainly owing to their flourishing birds'-nest industry. Interest in the phosphate deposits is thought to date from about 1870, but the first written record of their investigation is contained in a letter, dated 1922, from J. K. Beasley to the Borneo Company, in which he states: "In the caves I found where Mr. Everett had bored some years ago to prove the depth of guano and also pits that were reported to have been opened recently by Dr. Hose . . ." The working of guano appears to have been initiated about 1928 and has continued spasmodically up to the present day. In 1947 Mr. T. Harrisson, Curator of the Sarawak Museum and Government Ethnologist, visited the Niah Caves and made a reconnaissance examination of the guano deposits. The Agricultural Department have had analyses made of several samples of the phosphate and are also responsible for supervising the working of the deposits.

Gunong Subis consists of beds of massive Miocene limestone, forming a faulted dome structure elongated from north-east to south-west. The limestone is a hard, grey or buff, fine-grained rock, frequently crowded with Foraminifera. Calcite veinlets are common, and thin irregular veins of clay and iron oxide forming stylolites were seen at some localities. During the investigation of the phosphate deposits in this mountain, samples of limestone were collected from eight localities near both Gunong Brangin and Gunong Bekajang, and also from the base of the western side of Gunong Subis. Subsequent analyses of these samples by the British Aluminium Company indicate that large quantities of limestone suitable for the manufacture of Portland cement occur at Gunong Subis,

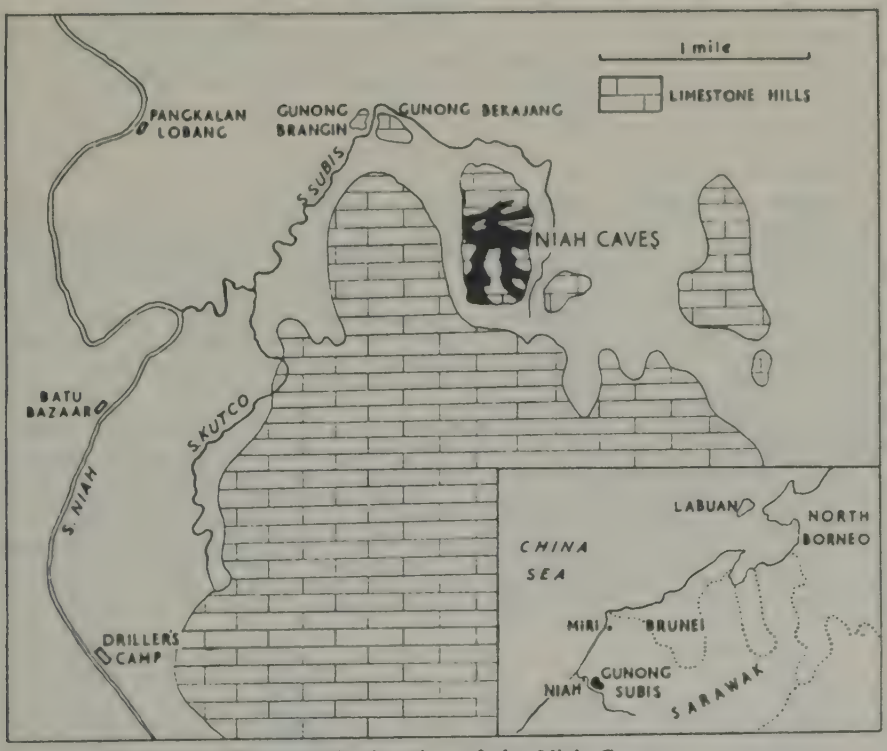


Fig. 1. The location of the Niah Caves.

1. This paper is a synopsis of two articles which appeared in the *1951 Annual Report of the Geological Survey Department, British Territories in Borneo*

within a mile of the Niah River. The limestone, being fine-grained and of high purity, could also be used for the production of lime. In addition the rock would probably be a satisfactory stone for tar-sealed roads.

The Niah Caves consist of about two miles of explored passages, covering an area of about twenty-three acres. Entrances to the caves are located on the east, west and south sides of Gunong Subis, and connections with the surface occur in at least five places in the roof of the caves. Small streams and water seepage from the roof are common. The passages are of two main types: (1) Narrow, high, rift-like passages, connected laterally by tube-like passages of small diameter. The rift-like passages are seen to follow the major direction of jointing and calcite veining in the limestone. (2) Broad, long passages, about 100 ft. in height and 120 ft. in width. These passages, where they coalesce, form large chambers as much as 300 ft. in diameter and 200 ft. in height. The floors are typically covered with large limestone boulders of clay and the guano and rock-phosphate deposits. Selenite occurs in both clay and phosphate.

The phosphate deposits originate chiefly from the accumulation of bat and swift droppings and the remains of insects which live in them. The deposits have taken thousands of years to form and, during this time, have reacted with the limestone and clay of the cave floors to form rock phosphate. The bulk of the phosphate is either dry or slightly damp; only in a few localities is it wet. Deposits averaging more than six inches in depth cover a total area of 150,000 sq. ft.; thinner deposits have been omitted in calculating reserves. The greatest depth of phosphate proved by pitting was 29 ft.; the average depth attained in twenty-four pits was a little more than 11 ft. The deposits are of two types:—

(1) *Guano.*—This consists mainly of organic materials; it is a soft, moist, dark-brown to black deposit which gives off ammonia, and has accumulated on steep (30°–50°) slopes in two main areas in the caves. The generation of ammonia is probably due to the concentration of urine dropped from birds and bats which live in the roof of the cave above the deposits. The guano has the consistency of wet sawdust and consists of chitinous insect remains and a black clay-like substance. The fresh bird and bat droppings are clay-like and white but are soon digested by numerous insects, and it is the remains of these insects which give the guano its dark colour.

(2) *"Fossil" Guano and Rock Phosphate.*—Deposits of this type consist mainly of aggregates of mineral particles. The material is soft, dry, powdery, reddish-brown, dark-brown and cream, often containing nodules of the mineral newberyite together with buff, nodular phosphate rock at various depths. The surface layers of these deposits were sampled to a depth of one foot with a view to determining if they differed considerably from the underlying material, or whether they were transitional to the guano which in part overlies them. This surface layer is generally damp and dark- or reddish-brown, but analysis shows that chemically it is more closely allied to the underlying deposits than to the overlying guano.

A hard, white rock-phosphate, replacing limestone boulders or the limestone of the cave floor, was found in some pits. Where the phosphate deposits rest on a clay floor the clay is altered to rock phosphate to a depth of several feet, and fissures, apparently due to contraction in the clay, are filled with a breccia of soft, powdery phosphate mineral. In one pit a layer of pale-blue material occurs, interbanded with soft, cream and brown "fossil" guano at a depth of six to seven feet.

Reserves of guano and rock phosphate are estimated to amount to at least 28,700 tons; 500 tons is surface guano containing about 5 per cent N and 4·5 per cent P_2O_5, and the remaining 28,200 tons "fossil" guano and rock phosphate containing an average of 23 per cent of P_2O_5. The nodular rocks and rock phosphate, which form less than 5 per cent of the whole deposit, have P_2O_5 contents varying between 9·3 per cent and 42·6 per cent.

Guano production from the Niah Caves appears to have started about 1928. In 1930 the output began to increase and a monopoly for collection and sale was granted to Kim Guan of Miri, who worked the deposits until 1944, when the Japanese took them over. The monopoly holder paid a royalty of M$0·25 per picul[1] (M$4·20 per long ton) on guano sold in Sarawak, and 10 per cent *ad valorem* on exports. In 1945 the deposits were worked under contract for the British Military Administration, and in July 1947 the Sarawak Agricultural Department became responsible for supervision of production and distribution. Kiat Siang, successor to Kim Guan, is at present extracting the guano; until recently the royalty was M$350 per month and a monthly output of up to 1,000 piculs was allowed. The recorded production is as follows:—

	Piculs	*Long Tons*
1946	3,380	201
1947	4,684	279
1948	7,056	420
1949	8,400	500
1950	10,800	643
1951	10,903	649

1. One picul = 133⅓ lb. avoirdupois.

Guano is at present collected from the Niah Caves by hand labour and carried about one and a half miles to a store at Pangkalan Lobang on the Niah River. From there it is taken by launch to Miri and other coastal towns in Sarawak and Brunei. The terrain between the caves and the godown is for the most part low-lying, flat and swampy. Planks of bilian raised on stilts two to three feet above ground level provide a path over the more swampy parts and planks and ladders are used in rocky areas adjacent to limestone hills. The Subis, a small stream, is normally too shallow and full of obstacles for the guano to be transported by boat.

North Borneo

Guano deposits, together with insect remains, and underlain in places by rock-phosphate, also occur in a number of caves in the colony of North Borneo, and in 1951 three groups of these caves were examined. The largest deposits were in the Gomantong and Madai Caves in the East Coast Residency, where pitting showed nearly 12,000 tons of phosphate to occur. Less than 400 tons of phosphate were found in the Mensuli caves, near the Segama River and about fifteen miles west-north-west of Lahad Datu; and an even smaller amount is thought to be present in the Baturong Caves, thirteen miles west of those at Madai. There are reports of guano deposits in caves near Bilit, Lamag and Kuamat in the Kinabatangan River valley, on Berhala Island near Sandakan, and on Mantanani Island west of the Kudat Peninsula; accounts indicate that these are probably small, and they were not investigated (Fig. 2).

The Gomantong Caves are located in the north-eastern end of a limestone hill situated some twenty miles south of Sandakan, East Coast Residency. The hill is an escarpment about a mile long and is built of bedded Tertiary limestone dipping about 250° NW. The limestone is fine-grained, pale-buff, and parts of it consist of large fossil corals. Joints in the limestone trend between north and north-north-east.

The first investigation of these deposits appears to have been made prior to 1889 by J. H. Allard of the China Borneo Company. It is recorded in the *British North Borneo Herald* for 1st September, 1889 that "Mr. Allard thoroughly tested the various guano deposits, in the Simud Hitam and Simud Puteh and he reported the total contents of the caves to amount in his estimation to 19,000 sq. yards of guano deposits, the greater part of which he considers to be of poor quality". Traces of pits alleged by nest collectors to have been made over fifty years ago can still be seen in the caves. In June 1941, G. S. Brown of the Forestry Department, Sandakan, investigated the deposits, collecting samples with an earth borer. He estimated the total amount of guano to be 11,900 cubic yards.

There are two main caves in Gomantong hill which are known locally as the Simud Puteh and Simud Hitam caves. The two chief entrances to the large cave, Simud Puteh, are reached by a steep, rocky path from a building at the base of the limestone hill. The cave consists of two types of passages developed along bedding planes and joints in the rock. The passages developed along bedding planes are roughly circular or elliptical in cross section; their roofs are typically scalloped, and the walls have shallow vertical flutings in some places. The floors are partly solid rock and partly covered with boulders and phosphate deposits. Typical bedding-plane passages are Buli Tinobatang, Bapa Tinobatang, Kundong, Kulibang-bang, and Ulun-ulun. The passages Bobong Bulod, Buli Has, and Badatan are developed along prominent joints and have a typically pointed, arch-shaped cross section. The joint passages are high (Bobong Bulod is about 450 ft. in height), frequently reaching the surface of the hill, the walls are commonly fluted, and the uneven floors covered with mounds of boulders and some phosphate. Simud Hitam is smaller than Simud Puteh, but the passages are much larger and a gap in the roof which opens out just below the entrance to Simud Puteh gives sufficient light for exploration without the use of lamps. The fluted walls of the large passages are vertical, and the floor and roof are parallel to bedding planes which dip about 250° NW. Small tube-like passages parallel to bedding planes occur in and near the roof.

Three main types of phosphate occur in the Gomantong caves.

(1) *Guano: type I.*—This is a soft, dark-brown material containing abundant chitinous insect remains and live insects, particularly cockroaches, near the surface. It has the consistency of damp sawdust and invariably a strong smell of ammonia. This is a recent surface deposit and forms characteristic conical accumulations and thin spreads overlying older deposits on the cave floor beneath the present resting places of birds and bats.

(2) *Wet clay-like guano: type II.*—Wet, often water-logged, soft, dark-brown or chocolate-brown deposits. The upper part contains insect remains but below the deposit consists of a clay or sandy clay. A covering of type I guano a few inches thick is often present. Type II guano occurs in quantity in low-lying areas in the caves and appears to be an accumulation of surface guano and other débris brought down by streams and water seepages.

(3) *"Fossil guano": type III.*—This consists of dry or damp, white, cream, buff, orange to dark-brown and black, rarely blue-coloured, deposits which vary from soft clay or sand to hard

rock-phosphate. This type of deposit occurs beneath the surface guano and is also well exposed in areas not now frequented by birds and bats. It is commonly well exposed between limestone boulders and appears to be an old deposit consisting of mineral particles and very little organic material.

Fig. 2. Positions of caves in North Borneo.

Nearly 15,000 cubic yards, or approximately 12,000 tons, of phosphate of all types are estimated to be present in the Gomantong caves. Types I and II when air dried have an average P_2O_5 content of about 10 per cent, but type III, the older "fossil" guano, contains just over 20 per cent P_2O_5 on an air dried basis. In the deposits, types I and II grade into each other and, though physically different, their P_2O_5 contents are almost identical. The P_2O_5 content of type II shows greater variations due to the fact that the deposit is an accumulation of débris from types I and III, brought down by streams and seepages which also carry non-phosphatic débris that dilutes the deposit. Chemically they differ chiefly in water content; the greater content of type II being due to the presence of water that has percolated from the roof and walls of the caves.

The chief problem in utilizing the phosphate deposits would be transport between the caves and a wharf on Sungei Lamba, a small tidal river navigable by motor boats and launches. At present nest collectors use a track about nine and a half miles in length to reach the caves. The first six miles of the track from Sungei Lamba is over flat ground, but nearer the caves the terrain is hilly or undulating. Transport of phosphate over this distance by porters would appear to be expensive and uneconomical; the Forest Department has considered the use of pack animals for carrying birds' nests and phosphate from the caves, and also road transport, though the cost of constructing and maintaining a road would be high.

Madai Caves. At Madai there are some twenty-five caves, most of them small, in limestone hills about twenty-seven miles south-west of Lahad Datu. The main Madai Cave and the Pidtong Caves are the only ones thought to contain much phosphate. The main Madai Cave is situated at the eastern end of Gunong Pidtong, a steep-sided limestone mountain. The cave passages penetrate the mountain from north to south and reach the surface at many places. Sungai Madai, a small stream which passes through the mountain flows northwards through some of the lower cave passages.

The limestone exposed in the Madai caves is a white, coarse-grained rock cut by numerous calcite veins, one of which, outcropping in the cave where Sungei Madai enters the mountain, contains calcite crystals as much as two feet in diameter. Bedding in the limestone is indistinct, and joints appear to follow no regular direction. Fossils, mainly corals and gastropods, are common in some parts of the rock. The main cave system comprises about 3,000 ft. of passages, which average

40 ft. in width and vary from 6 to about 400 ft. in height. The taller passages are open to the surface and seepages of rainwater are common. The floors of the passages are normally covered with boulders, clay and phosphate. In the lower passages clay and phosphate are rare and the limestone floor is exposed owing to erosion by the Sungei Madai. Spreads of gravel and logs of timber deposited by the stream during floods are common. The gravel has been cemented in places by lime, deposited by water from the roof, to form a hard conglomerate.

THE PIDTONG CAVES are about a quarter of a mile north-west of the main Madai Cave and due north of the summit of Gunong Pidtong. Two of these caves, named Pidtong and Pusu Samang Alag, contain phosphate. The entrances to Pusu Samang Alag, like several other caves in the area contain pieces of wooden coffins, human bones and pottery. Fragments of stone and chert are strewn about the cave floors having most probably been brought there by cave dwellers. Most of the phosphate deposits in these caves are wet owing to water falling directly from the roof or percolating laterally from seepages down the cave walls.

RESERVES. It is estimated that a total of 8,400 long tons of phosphate (approximately 10,500 cubic yards) occur in the Madai Caves. The following factors are important if the deposits are to be worked for despatch to settlements in Darvel Bay and beyond.

(1) *Ownership.*—The caves are privately owned and an agreement with the local proprietors who collect birds' nests from the caves would be necessary. Discussions with nest collectors during the present investigation seemed to indicate that it would be difficult to secure their agreement. The main reasons were the fear of disturbing the swifts during the nesting season and the fear that removing the phosphate would expose jagged rocks on the cave floor which would be a danger to them if they fell while gathering nests. Furthermore, the nest collectors receive a relatively high income from the sale of birds' nests at the present time and are not keen for outside labour to enter the caves and work the phosphate.

(2) *Water content of the deposits.*—The bulk of the phosphate in the Madai Caves is wet and it should be dried before transport in order to lower costs.

(3) *Transport.*—The phosphate could be carried by porters from the caves to a place on a tributary of the Madai which could be reached by small sailing craft or shallow-draft motor boats. The distance from the caves to this point is about three miles, which probably takes two hours or more when a heavy load is being carried. There appears, however, to be no suitable alternative as the construction of a light railway over the distance would be both expensive and difficult owing to the hilly nature of the ground near the caves.

The maps in this volume have been drawn by Mr. Poon Puay Kee.

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